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STUDIES ON THE MATURITY AND FECUNDITY OF THE GANGETIC ANCHOVY, *SETIPINNA PHASA* (HAMILTON)

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Introduction

Recordings of fish landings at Sadiapur Fish Assembly Centre, Allahabad, reveal that several species of clupeids represented by *Setipinna phasa* (Ham.), *Gadusia chapra* (Ham.), *Gonialosa manminna* (Ham.), juveniles of *Hilsa ilisha* (Ham.) and *Corica soborna* (Ham.) together constitute a moderately significant portion of the miscellaneous fishery. The miscellaneous group at Allahabad made up 18,360; 12,310 and 14,963 kg. respectively in the years 1958–1960 and contribution of *S. phasa* in these catches amounted to 588; 1,299 and 1,669 kg. This upward trend in the fishery of *S. phasa* at Allahabad, as evidenced from the landings, is quite significant and if maintained, the fishery may eventually assume a greater economic importance.

S. phasa, popularly known as 'phasa' in Bengal, is locally known as 'Patara' (meaning leaf-like due to its laterally compressed body). It is distributed in the estuaries of Orissa, Bengal, Cachar and Burma (Day, 1889). Jones and Menon (1952) observed that it abounds in all the deltaic branches of Ganges and is caught far above the tidal limits. The maximum size of *S. phasa* recorded at Allahabad is 324 mm. and according to Day (*op. cit.*) it attains at least 16 inches (406 mm.) in length.

Very little is known about the biology of *S. phasa* except for the observations on its early life-history (Delsman, 1932; Nair, 1940; Jones and Menon, *op. cit.*) and some stray notes on its bionomics (Mookerjee and Mookerjee, 1950; Jones and Menon, *op. cit.*). However, considerable work has been done on the anchovies particularly from Australian (Blackburn, 1948) and American (Clark, 1931; Clark and Phillips, 1952) waters. The present contribution deals with the maturity and fecundity of *S. phasa* of the Ganga river system at Allahabad.

Material and Methods

The material for the present study, which covered the period 1958–61, was obtained regularly from the catches landed at Sadiapur Fish Assembly

Centre, Allahabad, and by operating composite type of 'Mahajaal' (a drag-net) in the quiescent sections of rivers Ganga and Jamuna at Allahabad. The total number of fish examined for gonadal studies was 1,087, covering all the size ranges. For microscopic observations, however, the study was restricted to 109 specimens only, representing all the stages of maturity. Each fish, when brought to the laboratory, was measured as to the total length, fork length and standard length in mm. and weight to the nearest gm., and then dissected open to remove the ovary which was cleaned of the peritoneal and vascular tissues and its length and weight recorded accurately in fresh condition. Ovaries were, thereafter, preserved in 5% formaldehyde to permit hardening of ova which would facilitate maturity and fecundity studies.

Preliminary examination of ova taken from various parts of the two lobes of the ovaries in different stages of maturity showed that progression of ova-development throughout the ovary mass was not differential and ova were found to be evenly distributed throughout the ovary. Consequently, it was found convenient to take the central region of an ovary as a representative sample for maturity and fecundity studies. For each ovary examined, randomised samples of 300 ova were measured according to the methods recommended by Clark (1934), Schaefer (1936) and June (1953).

For fecundity studies a portion of mature ovary was weighed accurately in a chemical balance and all the mature ova, present therein, were individually counted. On the basis of the weight of the entire ovary, fecundity was then computed.

Seasonal Changes in Gonad Condition

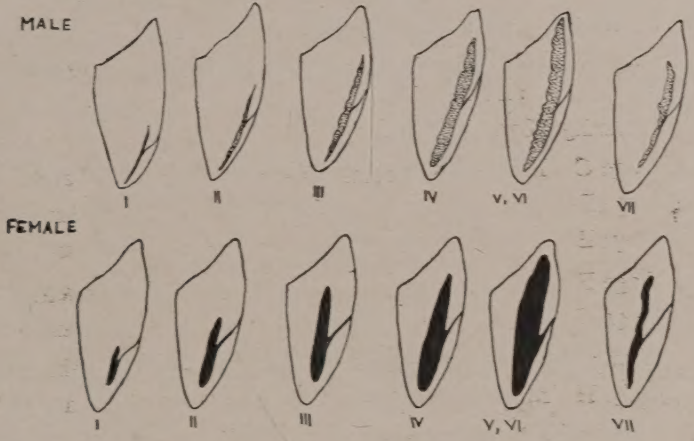
Description of a Mature Ovary

The mature ovary of *S. phasa* is a paired elongated organ, almost round in cross-section, attached to the dorsal wall of the body cavity by a mesentery, the mesovarium. The mature ovary occupies nearly the whole of the body cavity. Posteriorly the two lobes unite to form an oviduct opening to the exterior through the urogenital pore. Both the lobes are almost equal in length but in a few specimens the right ovary was found to be slightly larger. In a mature ovary the blood vessels become very conspicuous imparting a blood-red hue to the ovary.

Macroscopic Observations

Hjort (1911) described seven distinct stages of maturity for the herrings of the eastern North Sea and Icelandic waters. This classification, with slight modification, was subsequently followed by a number of workers (Graham,

1924; Hickling, 1930; Hickling and Rutenberg, 1936; Fairbridge, 1951). The seasonal changes in the gonad condition of *S. phasa* necessitated macroscopic observations of the gonads every month and 1,087 ovaries were examined for these studies during the period of investigation; the ovaries were then subjected to detailed microscopic examination. Macroscopically, gonads of *S. phasa* can be classified into seven stages of maturity which nearly correspond with the seven stages of the International Scale (Wood, 1930), and the Text-Fig. 1 diagrammatically depicts the gonad size in relation to body cavity.



TEXT-FIG. 1. The diagrammatic representation of the male and female gonad size in relation to body cavity in *S. phasa* (lateral view).

Microscopic Observations

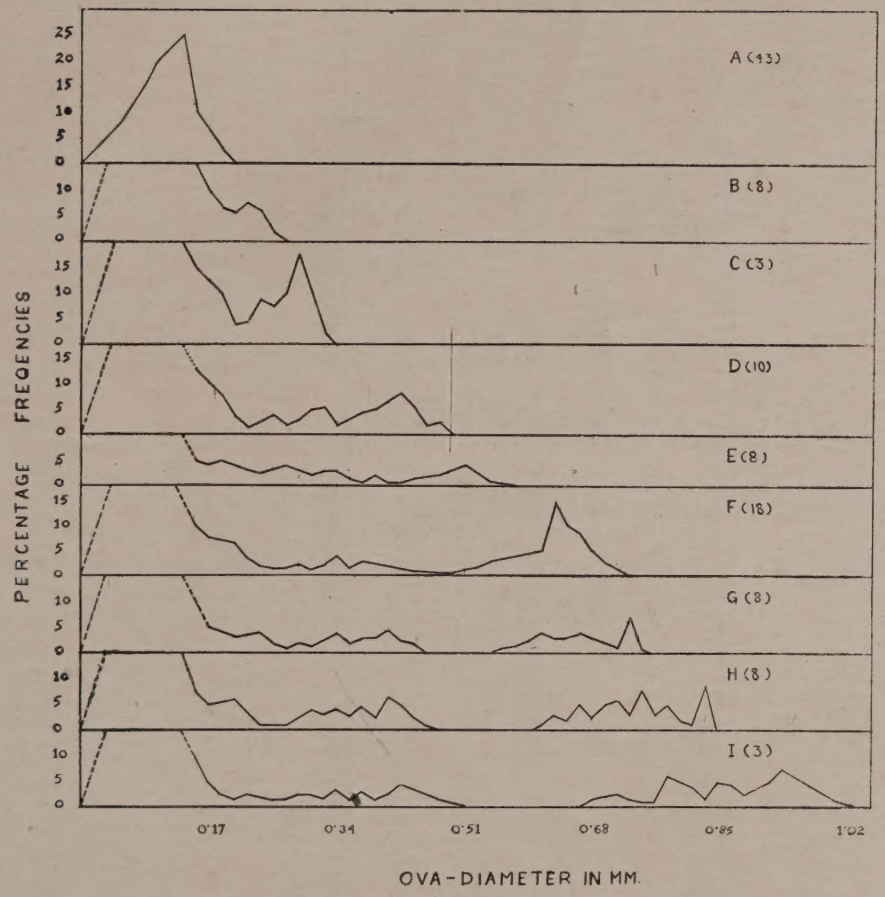
In a mature ovary a number of groups of developing ova may be distinguished. Clark (1934) working on the California sardine, *Sardina caerulea*, developed ova-diameter frequency polygons by grouping the data according to the location of the largest mode in the diameter frequency of the ova from each fish. Adopting a similar method in *S. phasa* the ovaries were classified into ten arbitrary stages of maturity as depicted in Text-Fig. 2. Each stage described below is compared with the International Scale (Wood, *op. cit.*):

Stage A represents a typical immature ovary where there is only one size group of ova, *i.e.*, those attaining a maximum diameter of 0·22 mm. Such immature ovaries were found in the months of January and June to December (Text-Fig. 3). However, a few ovaries examined in the month of September also fell exclusively into this category.

International Scale (Wood, 1930)	*S. phasa*
I	*Immature* (Ova transparent)
	Stage A Frequencies showing a mode at 0·14 mm. The ova reaching a maximum diameter of 0·22 mm.
II	*Intermediate* (Ova semi-opaque)
	Stage B Most mature group of ova appearing between 0·22 and 0·27 mm.
	Maturing (Ova opaque)
III	Stage C Most mature group of ova between 0·27 and 0·34 mm.
	Stage D „ „ „ 0·34 and 0·44 mm.
	Stage E „ „ „ 0·44 and 0·54 mm.
IV	Stage F „ „ „ 0·54 and 0·64 mm.
	Stage G „ „ „ 0·64 and 0·74 mm.
V	*Mature* (A few ova transparent but the majority still opaque)
	Stage H Most mature group of ova between 0·74 and 0·84 mm.
VI	*Mature* (Ova transparent)
	Stage I Most mature group of ova between 0·84 and 1·02 mm. with a distinct mode at 0·94 mm.
VII	*Spent* (Degenerating ova with dark yolk granules)
	Stage J Frequencies with ova larger than 0·22 mm.

Stage B shows the emergence of an intermediate group of ova from the immature stock with a slight mode at 0·22 mm. and extending in size up to 0·29 mm. The ova have increased in size and the yolk granulation in the cytoplasm has set in. In stage B and subsequent stages the immature ova are represented by dotted lines as they were in preponderance throughout the year. Stage B ovaries were encountered in the months October to January.

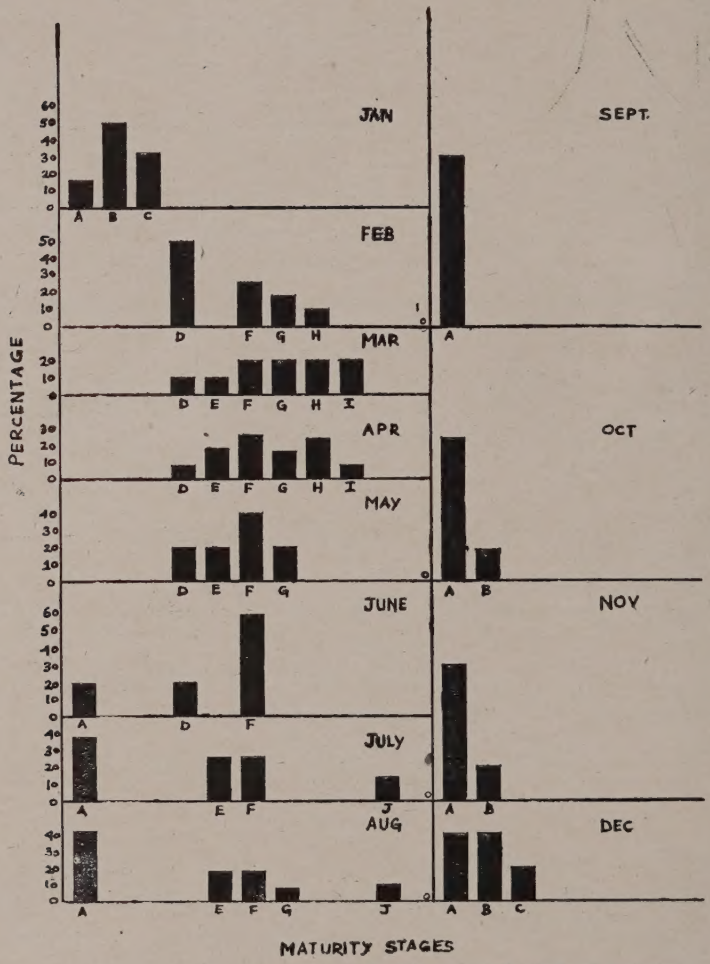
Stage C depicts the progression of the last mode of Stage B towards maturity. These ova when examined for their diameters were found to be



TEXT-FIG. 2. Ova-diameter frequency po'ygons showing the growth of immature ova towards maturity. The number of female specimens examined for each stage of maturity has been indicated on the right-hand side.

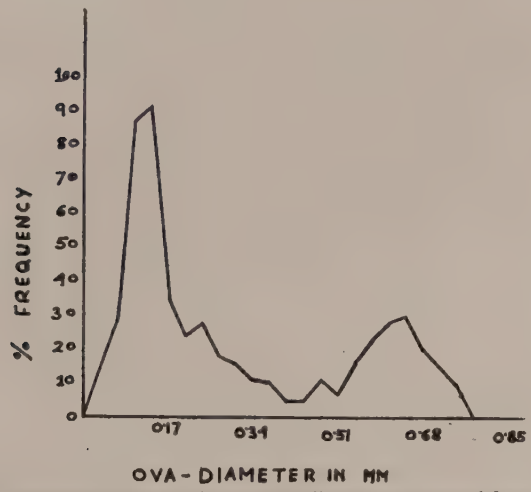
completely opaque due to the densely packed yolk granules present in the cytoplasm. The ova have considerably grown in size ranging between 0·27 and 0·34 mm. The ovaries in this stage of maturity were observed in the months of December and January.

In Stage D, the maturing group of Stage C has advanced further with a mode appearing at 0·42 mm. and with two other modes appearing at 0·25 and 0·32 mm. These ovaries were observed from February to June.



TEXT-FIG. 3. Monthly percentage of *S. phasa* in each stage of maturity.

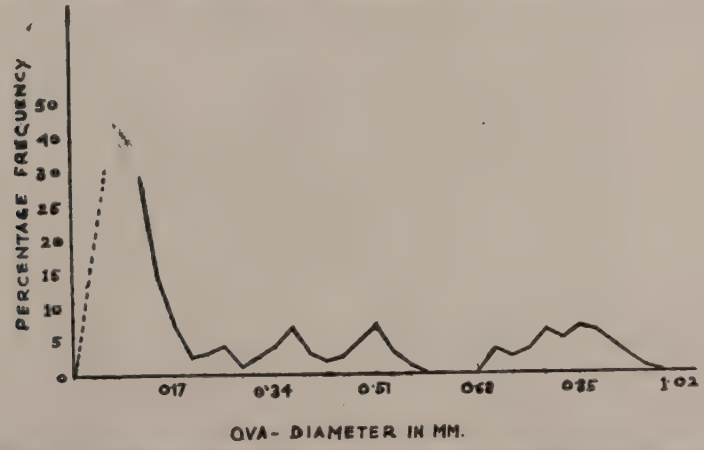
Stages E and F give indications of more maturing groups with distinct modes. Last mode of Stage D has shifted further forwards to a position having a mode at 0·51 mm. (Stage E). From this stage onwards the mode of immature ova is seen thinning down. It might be interpreted that henceforth only few ova develop from immature stage to intermediate group. Text-Figure 4 shows a typical maturing ovary in Stage F.



TEXT-FIG. 4. Frequency polygon of 1,000 ova diameters measured from a maturing ovary of *S. phasa* examined on February 26, 1959.

In Stage G the first maturing group of ova has separated itself from the rest of the stock and is about to mature. The mode of this group falls at 0·73 mm.

Stage H marks the attainment of maturity of the first maturing group of ova. Progressing further in Stage I they have become completely mature, ready to be shed. Ovaries in Stages H and I were observed in the months February to April. Text-Figure 5 represents the measurement of 1,000 ova



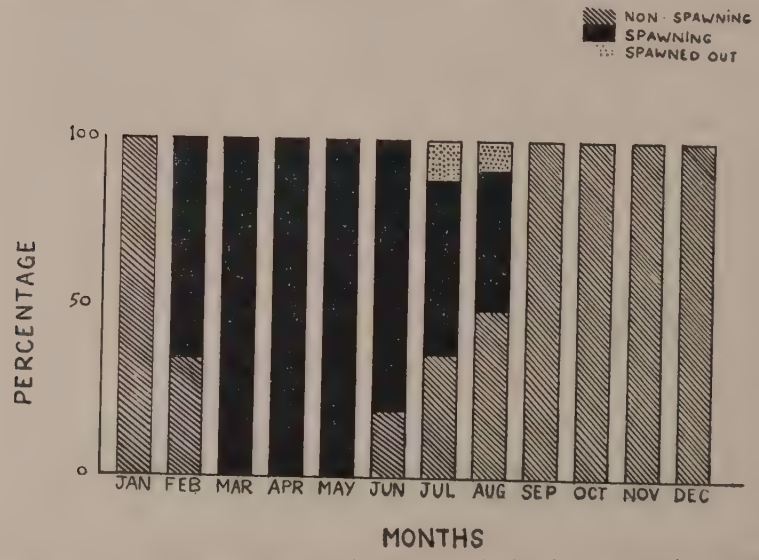
TEXT-FIG. 5. Frequency polygon of 1,000 ova diameters measured from a mature ovary of *S. phasa* examined on March 16, 1960.

from a mature fish 301 mm. in total length collected on 16th March, 1960. The group of ova ready for spawning is distinguishable from the maturing, intermediate and immature stocks of ova.

Spawning

Spawning Season

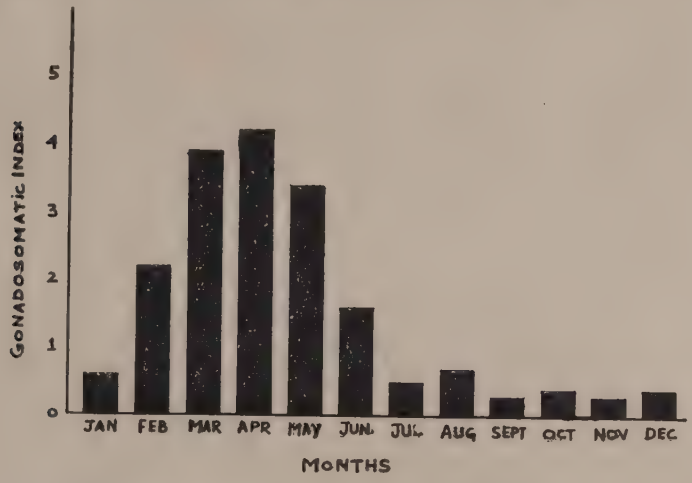
To establish the spawning season of *S. phasa*, monthly percentages of ovaries in different stages of maturity were calculated and plotted as histograms in Text-Fig. 3. It is seen that fish exclusively in immature and intermediate stages of maturity were observed in the months September to December and there was a complete absence of maturing and mature stages in these months. The early maturing Stage (C) makes its appearance in January and thereafter Stages D to I predominate from February to June. It may be mentioned that fish in F stage of maturity constituted about 60% in the month of June. Spent fish were encountered in July and August only. The presence of maturing and mature Stages (D to I) in the months February to August with spent fish encountered in July and August indicates that *S. phasa* has a prolonged breeding season commencing from about February and terminating by about August with peak breeding in the months March to May (Text-Fig. 6). It may, however, be mentioned that two ripe speci-



Text-Fig. 6. Monthly percentages of fish with ovaries in the non-spawning, spawning and spawned-out conditions.

mens were observed in October 1959 which might be suggestive of late spawning bursts in that month, although the occurrence of two ripe specimens as late as October appears to be an unusual feature since collections made in the same month of years 1958 and 1960 did not show ripe specimens.

The Gonadosomatic Index,* which is indicative of the breeding season in fish, has been calculated monthwise and depicted in Text-Fig. 7. There is



TEXT-FIG. 7. The spawning season of *S. phasa* as indicated by monthly ratios of ovary weight to body weight (Gonadosomatic Index).

a sudden rise in the values in February which is maintained in April with a very slight depression in May and thereafter the values are distinctly low with only slight rise in August. Thus it is seen that conclusions drawn from Text-Fig. 3 are substantiated by the monthly values of the Gonadosomatic index.

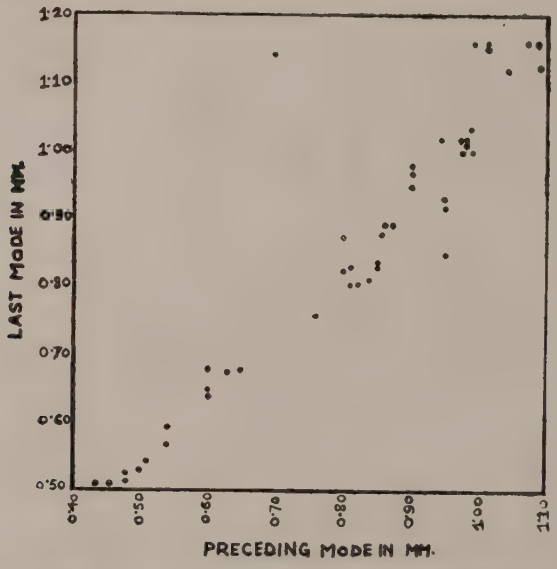
It is relevant to mention that *S. phasa*, according to Mookerjee and Mookerjee (1950), breeds in the tidal areas during the months, January to July, but according to Jones and Menon (1952) who collected developing eggs, larvae and juveniles from river Hooghly in and around Barrackpore, the peak breeding period in *S. phasa* is from October to November and during the rainy season only a few larval stages were collected.

Significance of the Multiplicity of Modes

Text-Figure 2 depicts the multimodal condition of the frequency polygoans appearing in practically all the curves of the maturing ova. It is seen that

* Gonadosomatic Index G.S.I. = Weight of ovary (gm.) × 100/weight of fish (gm.).

as the last group of ova advances towards maturity a second group is drawn from the immature stock which follows the same course of development. Similarly, other maturing groups also subsequently become differentiated. This would indicate that smaller groups also, in their turn, attain maturity and spawn in the same period. This is further clearly brought out from the comparison of the progression of the largest and the next preceding group of ova which is shown in a scatter diagram in Text-Fig. 8 where the last mode (Y) is plotted against the immediately preceding mode (X) in each of the



TEXT-FIG. 8. Scatter diagram showing relation between model groups of ova in the ovaries with E to I stages of maturity.

45 fishes in maturity Stages E to I. The high coefficient of correlation ($r = 0{\cdot}916$) indicates the positive relationship between the modes of successive ova-groups.

It may be mentioned that if a fish sheds only one batch of ova in a breeding season, a constant ratio between the maturing and mature ova is expected to be maintained throughout the breeding season (Clark, 1934). In *S. phasa* this obviously is not the case as can be seen from the comparison of number of all the ova larger than 0·51 mm. with the number of all the ova between 0·22 and 0·51 mm. from the fish in Stage F of maturity encountered during the three months, February to April (Table I). This period constitutes the commencement and peak breeding season.

TABLE I

Ratios of all ova between 0·22 *and* 0·51 *mm. to all ova larger than* 0·51 *mm. in the Stage F of maturity for the months February, March and April*

Date	Total length of fish in mm.	Ratio
February 12	265	5·01 : 1
14	247	3·60 : 1
18	261	3·79 : 1
18	282	4·06 : 1
27	243	3·88 : 1
	Average ratio for February	4·68 : 1
March 5	239	3·84 : 1
5	253	3·96 : 1
12	266	3·87 : 1
19	228	2·99 : 1
19	254	4·27 : 1
	Average ratio for March	3·79 : 1
April 2	270	3·00 : 1
11	272	2·98 : 1
19	235	2·84 : 1
19	245	2·08 : 1
22	220	2·42 : 1
25	263	3·11 : 1
	Average ratio for April	2·74 : 1

It is evident from Table I that there is a gradual decrease in the ratios of the two groups of ova and this progressive decrease can only be explained on the basis of successive spawning bursts during a particular spawning season. As shown by Clark (*op. cit.*) and June (1953) it is observed in *S. phasa* also that the decrease in the ratios of different ova groups is not effected by fish size (*cf.* Table I).

It may be argued that the secondary ova-groups (or maturing ova) are carried over to the succeeding season for spawning or that these groups suffer degeneration or resorption. The examination of all the ovaries during the period 1958–60 showed the presence of maturing ova in Stages C to G only during specific months of the year, February to August, and none of the ovaries revealed any indication of previous spawning. It may be mentioned that but for the two spent ovaries in July and August showing the

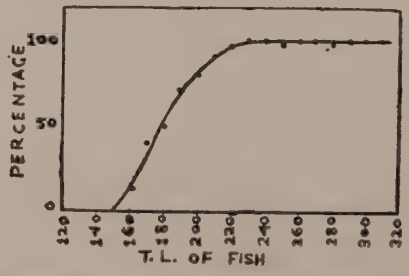
presence of a few dead, mature ova lying in the lumen, none of the ovaries examined in the non-spawning period September to January showed either maturing or mature ova. Consequently, the possibility of the smaller groups being carried over to succeeding season for spawning is not tenable. The examination of ovaries from September to January also did not show any degenerating mature ova.

Periodicity in Spawning

Considerable evidence is at hand to show that *S. phasa* does not follow a pattern of periodic spawning but on the other hand an individual might have a series of unrhythmic spawning bursts during the breeding season. Table II shows the sizes of maturing ova in the specimens examined in the months February to April which constitutes the commencement and the peak breeding season. According to Clark (1929), if spawning bursts follow a pattern of periodicity (as for example lunar periodicity) the specimens of fish collected on a particular day should show ova of approximately the same size which will progressively increase in diameter in relation to advancement of breeding season. Since, as shown in Table II the most immature as well as mature specimens with intermediate stages are encountered on a particular day, it is probable that in *S. phasa* there is no rhythmic periodicity in spawning bursts.

Size at First Maturity

The length of *S. phasa* at first maturity was determined by analysing the data relevant to all maturing females having ova larger than group B (0·27 mm.) collected during the middle of breeding season. Text-Figure 9 compares the percentage of females maturing at each length unit (10 mm. interval).



Text-Fig. 9. Length at first maturity of *S. phasa* as indicated by the percentage of female specimens maturing at each length unit (10 mm. interval).

TABLE II

The average diameter of ova of the maturing groups for individual fish collected on a particular day

Average diameter in mm.	February 1958		March 1958					April 1958		February 1959				March 1959				April 1959		
	12	18	5	12	14	16	19	2	4	2	6	11	12	1	8	10	15	6	12	28
0·26	3	2	1	..	..	1	..	..	..	..	1	..	..	..	..	1	..	1	..	..
0·32	..	1	1	1	..	..	1	..	..	..	..	3	..	1	..	..	..	..	..	1
0·38	..	..	..	..	..	2	..	..	..	4	2	..	..	..	..	..	..	..	..	..
0·44	1	..	..	..	..	..	..	..	1	..	3	1	2	1	3	1	1	1	..	..
0·50	..	2	..	..	..	..	1	1	..	..	1	..	..	2	..	1	..	..	..	2
0·56	..	2	..	..	..	..	..	..	..	2	..	1	..	..	..	..	..	..	1	..
0·62	4	1	1	1	1	1	..	..	..	..	..	..	1	..	2	3	2	..	..	..
0·68	..	2	..	2	2	..	1	2	1	..	4	2	..	2	..	..	..	..	2	1
0·74	2	..	..	1	..	..	..	..	..	..	..	..	1	..	2	..	..	..	..	2
0·80	1	..	..	..	..	..	..	3	..	..	2	3	..	1	..	2	3	1	..	1
0·86	..	1	..	..	4	1	..	1	..	3	..	..	3	2	1	..	2	..	1	..
0·92	..	..	..	1	..	..	1	2	..	..	..	..	1	..	..	4	2	1	..	2
0·98	1	..	..	..	2	4	2	1	..	1	..	..	..	..	2	..	3	1	1	..
1·04	..	1	1	2	..	5	..	5	1	..	..	..	..	..	..	1	2	..	..	..

The curve (Text-Fig. 9) indicates that none of the fish below 150 mm. were found maturing; 14% were maturing at 160 mm., 50% at 190 mm., 90% at 210 mm. and practically all the fish were mature at 230 mm.

Sex-Ratio

In *S. phasa* there are no external characters known which might help distinguish the sexes, although during spawning season there is a distinct bulging of abdomen in mature females. The present studies have, however, indicated that with the approach of maturity the caudal and paired pectoral fins in females develop dark colour along their margins, whereas in males the fin is uniformly white in colour. The sexual dimorphism characterised by different colouration of the pectoral and caudal fin is, however, not apparent in the early stages of maturity. Thus sexes were determined macroscopically after cutting open the fish. Table III gives the monthly distribution of the sexes in the samples for four years from 1958–61. It is seen that the two sexes are not present in the same proportion throughout the year. A significant rise in the number of females is observed from March continuing up to August which months constitute the spawning season of the fish. But in the subsequent months, the percentage of females is not so high which reflects a differential behaviour within the sexes during spawning period. If the grand total for the entire period of investigation is considered to be a true representative of the distribution of sexes then there would be 1,836 males to 3,532 females giving a ratio of 1 male: 1·92 females. With a view to finding out whether these samples had in fact been drawn from a population where males and females were equally distributed, the differences between the observed and theoretically expected ratio of 1 : 1 were examined by Chi-square test which showed that the observed ratio of males to females for the total sample differ significantly from the hypothetical 1 : 1 ratio. As is evident from Table III the sex ratio of the samples collected during non-spawning period is not significantly different from the expected ratio, it is likely that the actual ratio of the population is about 1 : 1 and the preponderance of females during spawning season may probably be due to differential fishing.

Relation between Maturity and Feeding Intensity

The observations made while studying the food and feeding habits of *S. phasa* revealed some correlation between the stage of maturity and feeding intensity. Table IV gives the seasonal fluctuations in the feeding intensity of the fish.

TABLE III

Monthly distribution of sexes in the samples of S. phasa *examined during the years* 1958–61

Months	1958					1959				
	Male		Female		Ratio (M : F)	Male		Female		Ratio (M : F)
	No.	%	No.	%		No.	%	No.	%	
January ..	27	40·3	40	59·7	1 : 1·48	68	43·9	87	56·1	1 : 1·28
February ..	11	34·4	21	65·6	1 : 1·90	88	34·9	164	65·1	1 : 1·86
March ..	9	18·8	39	81·2	1 : 4·33	57	24·1	179	75·9	1 : 3·14
April ..	16	31·4	35	68·6	1 : 2·19	32	24·6	98	75·4	1 : 3·06
May ..	10	20·4	39	79·6	1 : 3·90	15	20·0	60	80·0	1 : 4·00
June ..	4	13·3	26	86·7	1 : 6·50	16	12·0	117	88·0	1 : 7·31
July ..	3	10·7	25	89·3	1 : 8 33	25	12·1	181	87·9	1 : 7·24
August ..	1	7·7	12	92·3	1 : 12·00	2	8·0	23	92·0	1 : 11·50
September ..	24	39·3	37	60·7	1 : 1·54	35	71·4	14	28·6	2·50:1
October ..	39	32·8	80	67·2	1 : 2·05	71	42·3	97	57·7	1 : 1·37
November ..	26	33·8	51	66·3	1 : 1·96	37	35·9	66	64·1	1 : 1·78
December ..	9	47·4	10	52·6	1 : 1·11	55	45·8	65	54·2	1 : 1·18
Total ..	170	29·0	415	71·0	1 : 2·44	501	30·3	1151	69·7	1 : 2·30

Months	1960					1961				
	Male		Female		Ratio (M : F)	Male		Female		Ratio (M : F)
	No.	%	No.	%		No.	%	No	%	
January ..	48	53·3	42	46·7	1 · 14 : 1	33	36·3	58	63·7	1 : 1·76
February ..	75	83·3	15	16·7	5 · 00 : 1	67	37·8	110	62·2	1 : 1·64
March ..	36	16·1	188	83·9	1 : 5·33	54	60·0	36	40·0	1· 50 : 1
April ..	64	44·4	80	55·6	1 : 1·25	130	47·8	142	52·2	1 : 1·09
May ..	..	..	14	100·0	1 : 14· 0	90	21·7	324	78·3	1 : 3·60
June ..	25	39·1	39	60·9	1 : 1·56	20	23·5	65	76·5	1 : 3·25
July ..	..	..	..	..	...	14	29·8	33	70·2	1 : 2·36
August ..	14	14·7	81	85·3	1 : 5·78	30	28·3	76	71·7	1 : 2·53
September ..	111	45·5	133	54·5	1 : 1·20	29	26·6	80	73·4	1 : 2·76
October ..	22	29·3	53	70·7	1 : 2·41	127	52·0	117	48·0	1· 08 : 1
November ..	42	32·6	87	67·4	1 : 2·07	40	43·5	52	56·5	1 : 1·30
December ..	60	57·1	45	42·9	1· 43 : 1	34	26·1	96	73·9	1 : 2·82
Total ..	497	39·0	777	61·0	1 : 1·56	668	36·0	1189	64·0	1 : 1·78

Chi-square = 267·77; P = < 0·001.

TABLE IV

The seasonal fluctuations in the feeding intensity of S. phasa *determined as a degree of distention of stomach*

Months	Stomach: full–¾ full %	Stomach: ½ full–¼ full %	Stomach: empty %
October to January	55·0	28·8	16·2
February to May	18·6	21·3	60·1
June to September	21·4	22·9	54·8

In the months February to May the feeding intensity was considerably low (18·6%—stomachs full to ¾ full) with empty stomachs being 60·1%, which may be attributed to the commencement and peak breeding during these months. From June to September also the feeding intensity was comparatively poor. The months October to January constitute the period of active feeding.

FECUNDITY

The reproductive capacity of a population is a function of the fecundity of females. The number of eggs produced may differ in different species with differences in size and age of fish. Kesteven (1950) held that due to the variation in the composition of a population with regard to age and size and the dependence of fecundity upon these factors would mean variation from year to year in the total fecundity of the population, which when combined with the wide differences in the favourability of the environment for the reception of eggs, could cause changes in each year brood of the young stock. However, Merriman (1946) working on *Roccus saxatilis* observed that the changes in the numerical strength of the spawners had no significant effect on the strength of the coming brood.

Table V gives the fecundity of 10 specimens of *S. phasa* ranging in size from 160–282 mm. in total length. It is seen that the number of eggs increased with the size of the fish.

As *S. phasa* has been shown to breed more than once in a spawning season it must be understood that the fecundity as given in Table V cannot represent total ova production of an individual for the entire breeding season

TABLE V

Total ova production in 10 *female specimens of* S. phasa

Total length of fish mm.	Weight of ovary gm.	Ova per gm. weight of ovary	Total No. of ova (in one spawning burst)	Possible No. of ova maturing in one spawning season
160	18·8	214	4,018	12,054
166	22·5	207	4,668	14,004
209	60·6	163	9,898	29,694
209	42·0	193	8,124	24,372
225	61·7	316	19,483	58,449
239	75·8	172	13,033	39,099
243	73·0	160	11,644	34,932
253	86·5	214	18,471	55,413
265	101·6	192	19,483	58,449
282	113·9	246	28,028	84,084

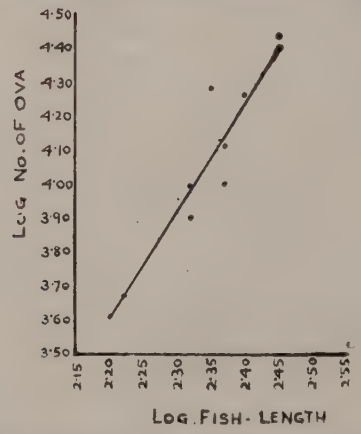
and this value can probably be achieved by multiplying the number of ova found in each batch by the number of spawning bursts. The data at hand, however, do not clearly indicate the number of spawning bursts in a season, but the comparison of the available data with that given by Clark (*op. cit.*) for California sardine, *Sardina cærulea* shows a remarkable similarity between the two species. The progressive depression in the ratio between the largest ova group and the preceding batches from 4·68 : 1 to 2·74 : 1 is comparable with that of California sardine which is about 4 : 1 to 2 : 1 (Clark, *op. cit.*). On the basis of this decreasing ratio Clark concluded that an individual of California sardine may mature an average of three batches of ova and that this number may be higher since there is no data to determine as to whether growth from immature to maturing class is accompanied by growth within the maturing sizes. As Text-Figs. 2 and 4 suggest such a growth it may be possible to estimate the total number of ova that will mature in one spawning season by multiplying total number of ova in one spawning burst by three.

Fecundity and Fish Length

It has been shown by a number of workers (Heidrich, 1925; Kesteven, 1942) that the number of ova holds some exponential relation with the length of the fish in the same way as does the weight. According to Kesteven (*op. cit.*) the gonad maintains size relationship with the remainder of the body of the organism and since the size of ova is constant in general, the number of eggs, being in effect a number of units of weight, will show an exponential relation with the length in the same way as does the weight of the entire organism. The relation between fecundity and length of *S. phasa* was determined by the method of least squares and a regression line fitted to the data. Fecundity and fish length show a high degree of positive correlationship with the coefficient of correlation ($r = 0{\cdot}848$). The relationship can be expressed by the equation:

$$\text{Log } Y = -3{\cdot}48796 + 3{\cdot}21997 \log X$$

where Y is the number of ova in thousands and X is the total length of the fish in mm. The relationship has been graphically depicted in Text-Fig. 10.



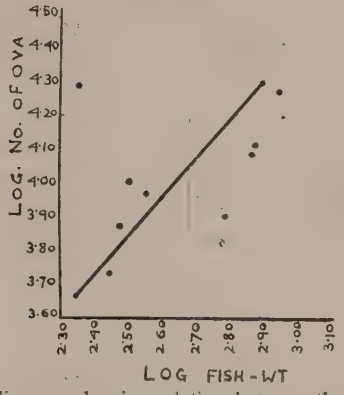
TEXT-FIG. 10. Scatter diagram showing relation between the calculated number of ova for one spawning burst and the total length of the fish.

Fecundity and Fish Weight

Smith (1947) studying fecundity in *Salvelinus fontinalis* stated that the number of ova was "related to the weight or volume of the fish than to the length". Simpson (1951) found in plaice that fecundity is related nearly to the cube of the length and is thus directly proportional to fish weight as will be observed theoretically because the number of ova are dependent upon the

volume of ovary and so should better correlate with the cube of the length. Allen (1951) while working on brown trout found that the relationship between number of ova and fish weight was curvilinear, but when he plotted the egg number against fork length it gave a straight line.

The fecundity data obtained were plotted against the total weight of *S. phasa* (Text-Fig. 11). A straight line relationship emphasising a high



TEXT-FIG. 11. Scatter diagram showing relation between the calculated number of ova or one spawning burst and the body weight of the fish.

degree of correlation ($r = 0{\cdot}945$) was obtained and can be expressed in the regression line as:

$$\text{Log } Y = 0{\cdot}41292 + 1{\cdot}41517 \log X$$

where Y is the number of ova in thousands and X is the fish weight in gm.

One value of 19,483 ova for 225 mm. length of fish appears to be on higher side and has not been taken into account in making these calculations as it is likely to effect the regression, disproportionately.

SUMMARY

1. To determine the stages of gonad development, the spawning time and length at first maturity, ova diameters of 109 specimens of *S. phasa* were recorded and 10 arbitrary stages of maturity were described.

2. *S. phasa* was observed to spawn more than once in a breeding season but no periodicity in spawning could be seen.

3. The spawning season was found to commence from February and terminate in August. The peak breeding was observed in the months March to May.

4. No specimen was found mature below 150 mm. and practically all were mature at 230 mm.

5. The feeding intensity was found to be low during spawning season.

6. The number of ova produced by a female in one spawning burst was found to range between 4,018–28,028 ova in specimens ranging in total length from 160–282 mm.

7. Fish length and fish weight were plotted against number of ova and linear relationships were obtained.

Acknowledgements

I am highly indebted to Dr. M. P. Motwani, Research Officer, and to Dr. D. N. Verma, Assistant Professor of Zoology, Allahabad University, for their encouragement and valuable suggestions. My thanks are also due to Shri B. N. Saigal for his help in the statistical treatment of the data.

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SOME OBSERVATIONS ON THE BIOLOGY OF *COILIA BORNEENSIS* (BLKR)

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Introduction

Coilia borneensis, locally known as "Amadi," is a medium-sized clupeoid very common in the estuaries of West Bengal. Day (1878) has recorded the species from Madras, Burma and the Malay Archipelago. The fish is more abundant in the middle stretch of the estuarine system than in the upper and lower zones.

Bag-net (Beenjal, Behundijal or Thorjal) is the main gear by which *C. borneensis* is caught, though it is also taken along with other fishes in the catches of barrier-nets (Chorpatajal) and shore-seines (Berjal).

Material and Methods

The material for this study was obtained from the commercial bag-net catches from thirteen centres distributed along the Hooghly, Matla and Rupnarayan estuarine system in West Bengal. In total, 3,464 specimens have been procured from the random samples collected at fortnightly intervals during a period of three years, from January 1958 to December 1960. It was observed, during the analysis of data on the spawning periodicity of the fish, that the species spawns at different periods in the Hooghly and Matla and Rupnarayan. Mature specimens occurred in the catches of Matla and Rupnarayan from the end of March to July and from March to June respectively. In Hooghly, they were obtained from November to January. This difference in spawning periods was taken to indicate the existence of at least two different physiological races. Hence, the length frequency studies were made only with samples drawn from Matla and Rupnarayan which appeared to be homogeneous stock. The samples, immediately after collection, were preserved in 5% formaldehyde and all the studies were done in the laboratory. Total length of the fish, from the tip of the snout to the longest caudal ray, corrected to the nearest millimeter, was taken on a measuring board. A trip-pan balance with an accuracy of 0·1 g. was used to weigh the fish. After the above measurements were recorded, specimens were cut open through the abdomen to remove the stomachs and to note the sex and stage of maturity. The maturity stages mentioned in this papsr correspond to the scale adopted by the International Council for the Exploration

of the Sea (Wood, 1930). The stomach contents were washed into a watch-glass and the identification of organisms was made either with naked eye or with a compound microscope, as required. The percentage of each item of food in the total stomach content was determined by eye estimation (Pillay, 1953). The condition of feed was decided by the degree of distension of the stomach.

In order to study the spawning periodicity of the species, ova diameter measurements from ovaries in different stages of maturity were taken with the help of an ocular micrometer. One micrometer division was found to be equivalent to 13·535 μ. Total counts of ova in IV and V stage ovaries were made for fecundity studies. For this purpose, the ovaries were treated with modified Gilson's fluid, by doubling the amount of acetic acid.

Length Frequency Distribution

As already stated, samples from Matla and Rupnarayan Rivers only, with a length range of 21–125 mm., are considered for this study. The 2,587 measurements are grouped into 5 mm. groups and a histogram is prepared as shown in Fig. 1, where there is only a single prominent mode at 53 mm. This is the length at which the species is caught in maximum numbers.

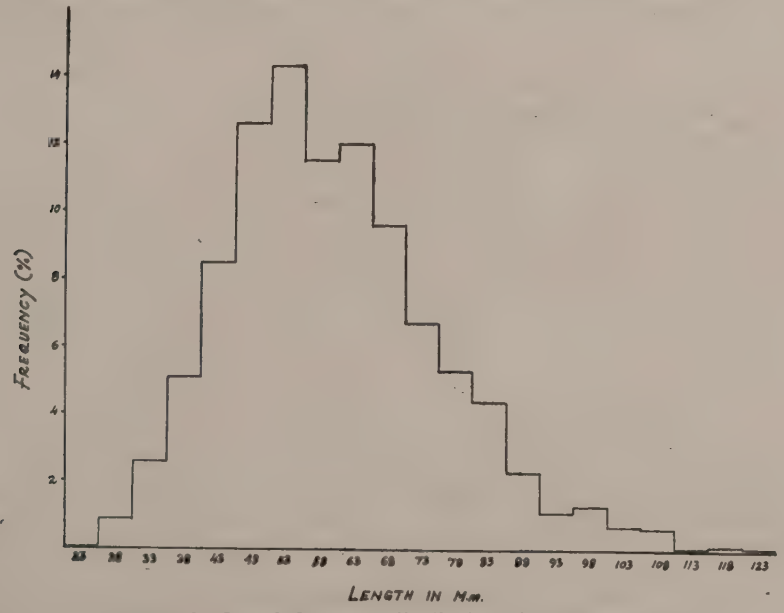


Fig. 1. Length frequency distribution of *C. borneensis.*

Monthwise length frequency histograms prepared with the above data are given in Fig. 2. In January, there is a distinct mode at 48 mm., while

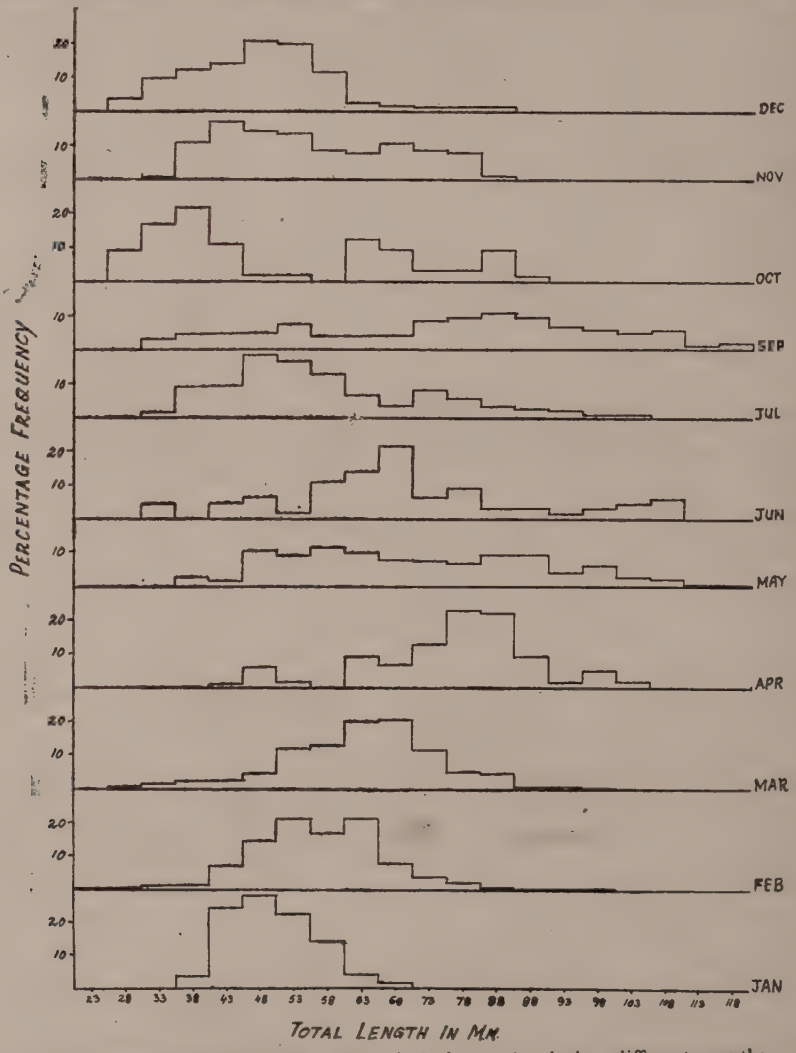


FIG. 2. Length frequency histograms of *C. borneeniss* during different months.

in February there are two close 'Peaks', at 53 mm. and at 63 mm. In reality, the mode seems to be at 58 mm., as it appears from the frequency histograms of other months that the fish grows about 10 mm. per month during the first year. The single prominent size-group of March has the moda

value at 68 mm. This size-group registers a growth of another 10 mm. in April, the mode being shifted to 78 mm. A small 'peak' at 48 mm. shows the entry of new recruits into the fishery. Two size-groups with modes at 58 mm. and 88 mm. are seen in May, indicating a growth of 10 mm. for both the size-groups of the previous month. In the succeeding month, the younger size-groups with the modal value at 68 mm. dominates over the bigger individuals. In July, the main 'peak' is at 48 mm. due, obviously, to the occurrence of new recruits, while the small second mode at 73 mm. accounts for the previous month's 66–70 mm. group. Since sufficient number of specimens could not be obtained, the length frequency for August is not included. There are two size-groups in September, with modes at 53 mm. and 83 mm. Addition of juveniles into the fishery is shown by the mode at 38 mm. in October. The second and third modes of the month at 63 mm. and at 83 mm. represent, probably, the early and late 0-year groups respectively. In November, two modes are seen, at 43 mm. and at 68 mm., accounting for the juveniles and early 0-year group of the previous month, while the late 0-year group disappears. In December, there is only a single mode at 48 mm., just as in January.

From the above data it appears that the rate of growth of the fish during the first year is about 10 mm. per month. However, in some months when the modes are formed of young specimens, the rate of growth is shown to be only 5 mm. This suggests that the growth of younger individuals is rather slow.

It is interesting to note that large specimens of *C. borneensis* are very scarce in the catches. The fishery is mianly made of 0-year group. Specimens measuring below 65 mm. alone account for 67·6% of the total number of individuals caught. Further, the fishery shows a definite periodicity. From Jnuary to May the species affords a good fishery. Thereafter it declines gradually and becomes very poor in August. From September the fishery shows a steady revival and good catches are made during the months of November and December.

Length-Weight Relationship

The length-weight relationship was calculated from measurements of 2,203 specimens ranging in length from 21–145 mm. Specimens were grouped into 5 mm. class intervals and the average weights of these groups were determined. These values, when plotted against the mid-points of the class intervals, an exponential curve was obtained. This shows that the weight of the fish increases as an exponential function of its length. The logarithmic

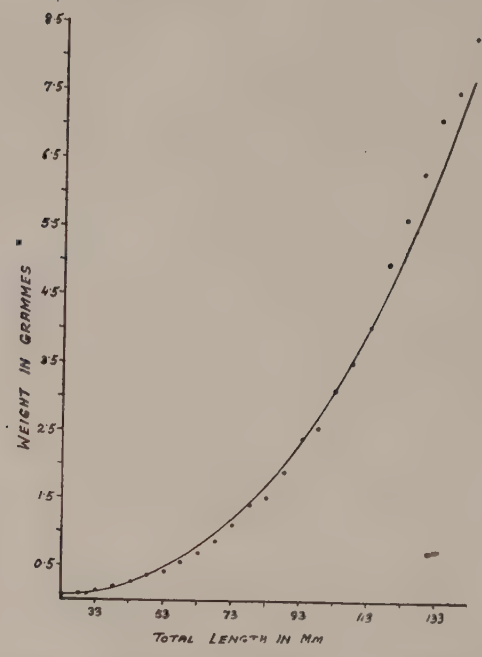


FIG. 3. Length-weight relationship of *C. borneensis*.

relation of length and weight was found to be a straight line. The correlation coefficient calculated for the above data was very high ($r = 0{\cdot}9971$) indicating the significance of the relationship.

The relationship between length and weight could be expressed by the formula $W = CL^n$, where $n = 2{\cdot}7490$ and $C = 0{\cdot}000009105$ (L = total length of the fish in mm. and W = the weight of the fish in grams).

PONDERAL INDEX

The ponderal index was calculated employing the formula KW^{10^5}/L^3 where K = condition factor, W = weight of the fish in grams and L = length of the fish in millimeters. The values of K were calculated separately for various size-groups and for samples collected during different months. Samples drawn from Matla and Rupnarayan only were considered for this study.

Figure 4 indicates that the 'K' values are very high in the small size-groups. The condition of the fish progressively decreases with increase in

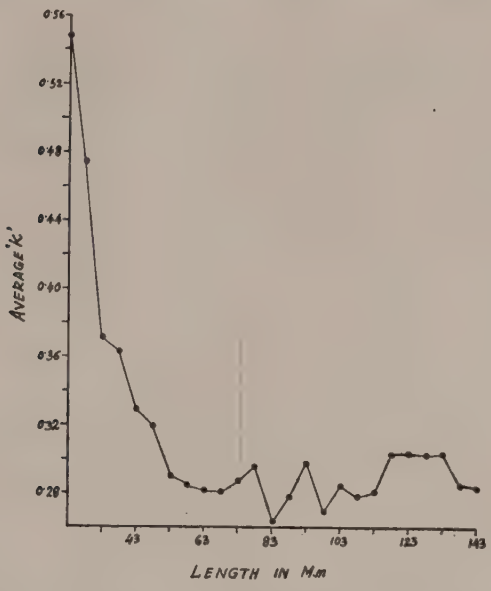
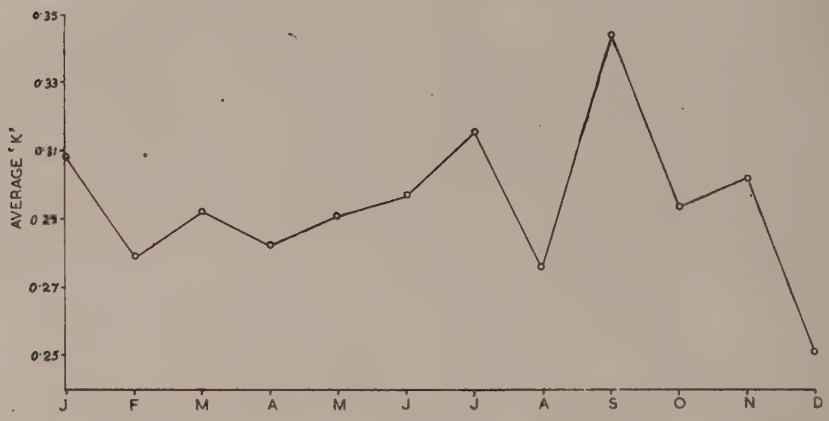


FIG. 4. Average 'K' at different lengths of *C. borneensis.*

length up to a length of about 68 mm., after which it shows a sudden rise. Such a rise is generally associated with the attainment of maturity. In the present instance also this increase in condition takes place at about the size when the fish attains maturity. Some evidence in support of this view is afforded by the fact that most of the individuals at this length are found to be sexually mature.

A study of the monthly fluctuations in the condition factor of mature *C. borneensis* (Fig. 5) shows the existence of three condition 'peaks', in January, July and September. The gradual increase in 'K' from February to July may probably be attributed to the developing gonads prior to spawning. The abrupt fall in condition during August and the increase in September may be attributed to the spent condition of the fish and the subsequent recovery respectively in these months. The condition 'peaks' in November and January may be due to the active feeding during these winter months when plankton, the main food of the species, is abundant in the estuary. However, the reason for the lowest condition in December is not clear.

Figure 6 shows the condition cycle of immature *C. borneensis.* Followed by a condition 'peak' in March, the fish retains uniformly high values of 'K' up to July. The condition values of August and September are not known



FG. 15. The monthly fluctuations in the 'K' values of mature *C. borneensis.*

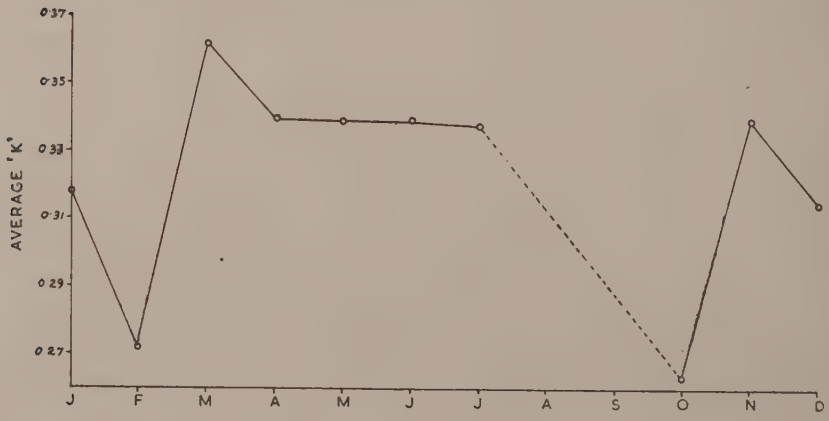


FIG. 6. The monthly fluctuations in the 'K' values of immature *C. borneensis.*

as immature specimens are either not represented or inadequately represented during these months. The lowest values of 'K' are in the months of October and February. The observed poor feeding activity of the fish, during these months, may be responsible for such low values. There is a sudden increase in condition in November and the values are maintained fairly high during the succeeding two months also. This seems to be associated with the intensive feeding activity of the fish during these months, as already mentioned.

Food and Feeding Habits

In order to assess the food of *C. borneensis*, stomachs of 571 specimens were studied. The percentage composition of various food items were calculated for different months (Fig. 7).

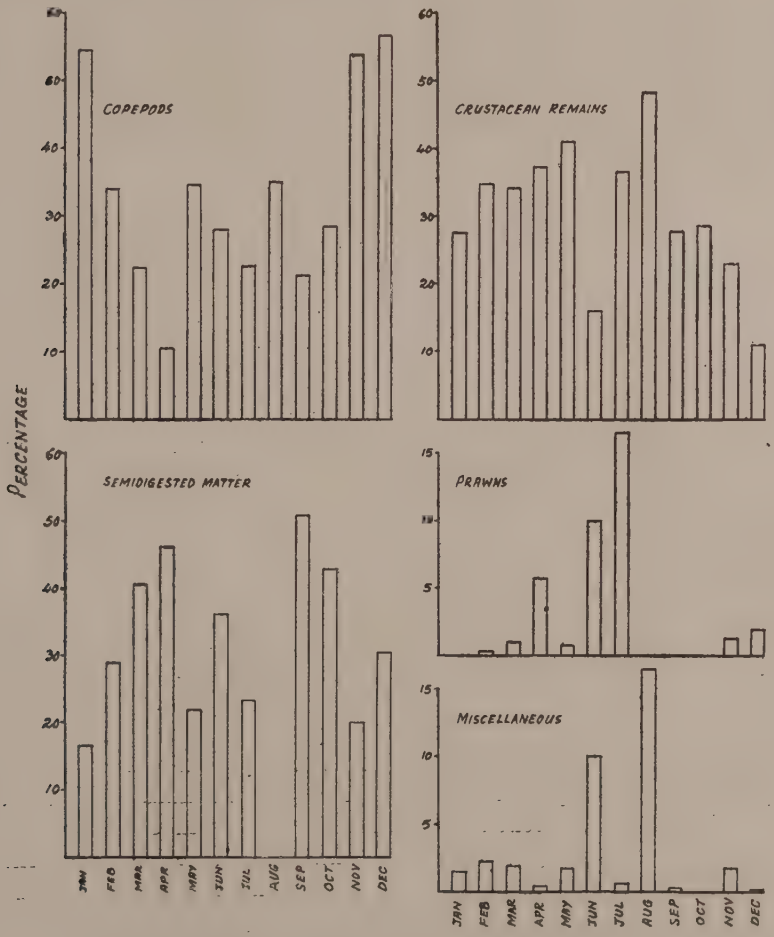


Fig. 7. Histograms showing the monthly variations in the percentage composition of the different items of food of *C. borneensis*.

Prawns and other small estuarine crustaceans formed the principal food of the fish. In the majority of stomachs, varying quantities of digested organic matter were present contributing to 29·8% of the total volume of

food consumed during the period of study. Certain organisms, which were found to be consumed occasionally, were listed as miscellaneous items.

Copepods

As a single item of food, copepods predominated during the entire period, accounting for 33·5% of the total volume. They were present in all the months and the most predominent period was from November to January. The lowest value was for April when they formed only 10·4%. *Acartiella* spp. and *Diaptomus* spp. were the two common forms present.

Crustacean Remains

It was not possible to specifically identify the various other crustaceans eaten by the fish since they were represented in the gut contents only by their appendages or other fragments of the body. This group ranked second by volume. However, it appeared that among the different pieces, those of copepods were dominant.

Digested Organic Matter

Various types of animal tissue in an advanced stage of digestion, appearing as pulpy-whitish matter, was encountered frequently in the stomachs, particularly in the less distended ones. This matter, further identification of which was not possible, accounted for nearly 29·8% of the total volume of stomach contents.

Prawns

Prawns, which formed 3·1% of the food, were found in the stomachs during the months of June, July, November, December and from February to May. Bal and Joshi (1956) found that prawns rank second in the food of *C. dussumieri*. They have also observed that prawns were consumed in comparatively smaller percentages by juvenile fish. A similar habit has been reported by Jones and Menon (1952) for *C. reynaldi*. In *C. borneensis* also, the juveniles and young ones were found to feed mostly on smaller crustaceans. In this connection it may be mentioned that the samples analysed for this study mainly consisted of young specimens.

Miscellaneous

Apart from the above main items of food, cladocerans (*Bosmina* spp.), nematodes, diatoms (*Coscinodiscus* spp. and *Stephanodiscus* spp.), megalopa larvae and sand particles were also noticed. As the quantity and prevalence

of such items were meagre, their consumption may be considered as accidental.

The seasonal variations in the feeding activity were studied by classifying the stomachs as 'gorged', 'full', '¾ full', '½ full', '¼ full', 'trace' and 'empty', depending on the degree of distension (Table I). From the table it appears

TABLE I

Showing percentage in the variation in the feeding intensity of C. borneensis during different months of the year

Month	No. of Stomachs	Gorged	Full	¾ Full	½ Full	¼ Full	Trace	Empty
January	44	..	6·8	2·3	22·7	31·8	36·4	..
February	54	..	..	3·7	24·1	22·2	38·9	11·1
March	53	..	3·8	5·6	18·9	28·3	37·7	5·7
April	34	..	..	3·0	14·7	38·2	35·3	8·8
May	43	..	..	4·7	11·6	27·9	53·5	2·3
June	34	..	8·8	..	23·5	29·4	38·3	..
July	35	..	2·9	5·7	22·8	14·3	45·7	8·6
August	28	..	..	12·5	25·0	37·5	25·0	..
September	24	..	..	8·3	12·5	12·5	66·7	..
October	18	..	12·5	..	..	12·5	62·5	12·5
November	89	..	1·1	9·0	16·8	31·5	41·6	..
December	115	..	9·6	13·0	11·3	13·9	46·1	6·1

that the feeding intensity of the species is very moderate. Gorged condition was not found in any of the stomachs examined. Specimens with even full stomachs were very few and totally absent in August, September, February, April and May. Majority of the individuals have been found to be in '¼ full', or 'trace' conditions, the latter being the predominant group. Varying percentages of 'empty' stomachs were also present except in June, August, September, November and December.

Sex Ratio, Spawning and Fecundity

Sex Ratio

From a study of a sample of 666 adult specimens of *C. borneensis*, it is seen that the ratio between females and males in the commercial catches is 1·1 : 1·0.

Spawning

Direct evidence on the spawning period of a species is afforded by the occurrence of mature and spent specimens in various months of the year. Ripe specimens of *C. borneensis* in IV, V and VI stages of maturity were found in the catches from March to July in the Matla river (Port Canning) and from March to June in river Rupnarayan (Kolaghat, Anantapur and Gobindpur). From Hooghly, however, a few mature specimens (IV and V stages) were obtained only in the months of November, December and January. Hence, in Matla and Rupnarayan rivers the breeding season appears to commence by the end of March and continues till July as evidenced by the occurrence of gravid and spent specimens in the catches. The number of individuals in advanced stage of maturity and spent condition is comparatively low during March and their number increases progressively till finally the largest percentage of oozing and spent adults is encountered in the commercial catches during July indicating that peak spawning takes place in this month.

It is interesting to note that the few mature specimens obtained from Hooghly (middle zone) were in November to January. Hence, the species seems to breed in this river during the winter months. The foregoing data suggest a possibility of the existence of different physiological races. However, detailed studies of the meristic characters are to be made before confirming the above view.

Ova measurements from ovaries in successive stages of maturity have been used to trace the mode of withdrawal of eggs to undergo maturation which throws light on the spawning habit of the species. The diameter measurements were grouped into 2 m.d. (micrometer division) to prepare the polygons. Ova measurements from different individuals in the same stage of maturity show no difference in the frequency distribution, which indicates similar spawning periodicity between individuals. Specimens collected from Port Canning alone were used for measuring the ova diameters.

Figure 8 A shows the frequency distribution of ova in stage II maturity, where there is only a single mode at 5-6 m.d. This mode shifts to 7-8 m.d.

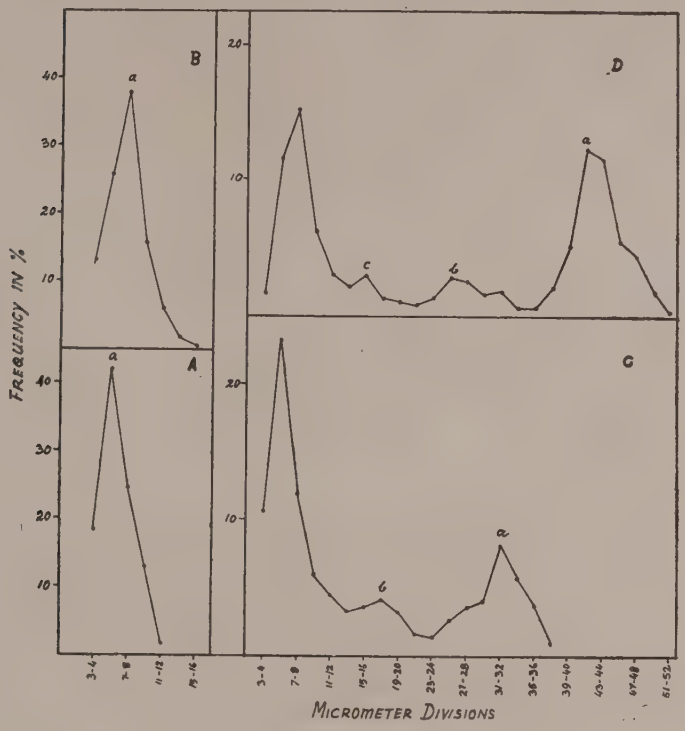


FIG. 8. Ova diameter frequency polygons.

in polygon B which is drawn from ova measurements from an early III stage ovary. Polygon C represents the distribution of ova in a stage IV ovary. The mode *a* is located at 31–32 m.d., while there is a second mode *b* at 17–18 m.d. formed by ova in the stage III of maturity which indicates the withdrawal of a second batch of eggs to undergo maturation. In polygon D, where the measurements are taken from a stage V ovary, the modes *a* and *b* are located at 41–42 and at 25–26 m.d. respectively. Further, there is a third mode *c* at 15–16 m.d. The ova at mode *a* are the first batch of eggs to be shed during the ensuing spawning season followed by that at *b* and *c*, in order of maturity. It appears, that by the time the eggs at mode *a* are spawned, the ova at modes *b* and *c* will undergo further development and occupy the positions of *a* and *b* respectively. As there are three batches of eggs undergoing maturation at the same time, it is concluded that each individual fish spawns for a long time and the eggs are shed in successive batches with a definite periodicity. These findings, along with the inference drawn on the

basis of the occurrence of mature specimens in catches, indicate that this species has a prolonged spawning season extending about five months.

Fecundity

Since the fecundity of only 25 specimens are studied during the present investigation, which is considered insufficient to establish any definite relationship with the length and weight of the fish, no attempt is made on these lines. However, the details of the fecundity counts are given in Table II. It is seen from the table that the fecundity varies from 578–2558 in the length range of 91–122 mm.

TABLE II

Showing the fecundity of C. borneensis

Sl. No.	Total length in cm.	Weight in gm.	Fecundity	Stage
1	10·2	4·3	1,495	IV
2	11·7	5·8	2,558	IV
3	9·4	3·2	810	IV
4	10·5	4·8	1,947	IV
5	12·2	6·4	1,942	IV
6	10·6	3·6	1,506	IV
7	9·8	3·5	651	IV
8	10·8	3·7	1,183	IV
9	10·8	3·4	1,842	V
10	9·1	2·5	578	IV
11	9·9	3·0	1,056	V
12	10·0	2·6	1,131	IV
13	10·7	3·4	1,504	IV
14	9·4	2·6	880	IV
15	10·3	2·8	1,176	IV
16	12·0	6·0	1,623	IV
17	11·0	4·0	1,603	IV
18	9·8	2·5	961	IV
19	10·2	2·8	941	IV
20	11·0	4·0	1,176	IV
21	10·4	3·0	850	IV
22	11·3	4·9	1,931	IV
23	11·2	4·8	1,450	IV
24	11·7	7·6	1,635	IV
25	9·4	2·5	692	IV

Summary

Some aspects of the biology of *C. borneensis* have been studied.

The length distribution shows that the commercial catch is mainly composed of 0-year group. Monthwise length frequency histograms suggest a rate of growth of about 10 mm. per month for the species.

The length-weight relationship may be expressed by the formula, $W = 0{\cdot}000009105\ L^{2{\cdot}7490}$.

The variation of ponderal index with the size indicates that the fish attains first maturity at about 68 mm. Fluctuation in condition during different months of the year is studied.

C. borneensis feeds mainly on copepods and on other small estuarine crustaceans. Monthwise changes in food and feeding intensity are studied.

Ratio of females and males in the commercial catches is 1·1 : 1·0. The spawning period of the species in Matla and Rupnarayan rivers starts in March, and probably, extends up to July, while ripe specimens from Hooghly are collected from November to January. Ova diameter studies of specimens from Matla suggests an extensive breeding period. Ovaries from 25 specimens are counted and the results are given in Table II.

Acknowledgements

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OBSERVATIONS ON THE DISTRIBUTION AND FLUCTUATIONS OF PLANKTON IN THE HOOGHLY-MATLAH ESTUARINE SYSTEM, WITH NOTES ON THEIR RELATION TO COMMERCIAL FISH LANDINGS

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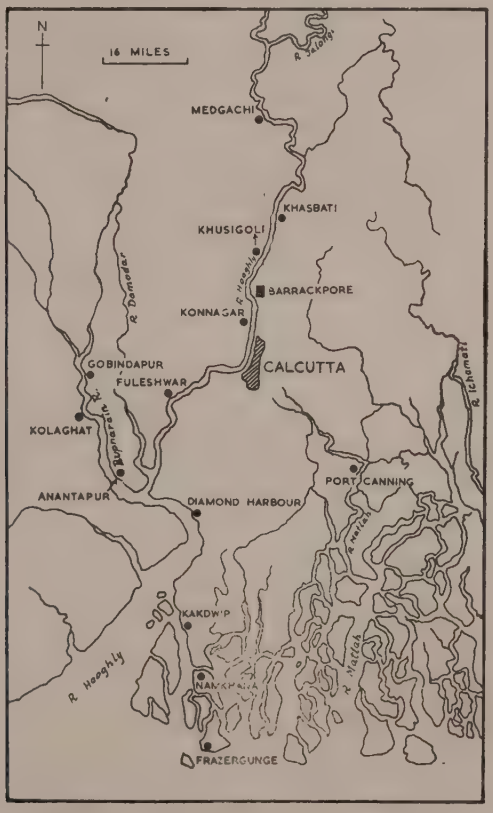
(Central Inland Fisheries Research Institute, Barrackpore)

Introduction

Observations on the plankton of the Hooghly-Matlah estuarine system were taken up in order to study its distribution and seasonal fluctuations, as part of a comprehensive study on the commercially important fish populations of the estuary. Some workers like Juday, Rich, Kemmerer and Mann (1932) and Ricker (1938) have attempted to relate fluctuations in plankton populations to the vital statistics of commercially important fishes. The significance of plankton studies in elucidating some of the probable factors responsible for fluctuations in abundance and movements of fish stocks is well known. The Hooghly-Matlah estuarine system is of great economic importance from the fisheries point of view and a detailed study of the plankton of this estuary is expected to throw some light on the pattern of fluctuations in its fisheries.

Data on the plankton and hydrology of the Hooghly estuary are yet rather meagre. Roy (1949 and 1955) has given accounts of plankton ecology for a small region of the Hooghly at Palta. Observations on the hydrology and seasonal fluctuations of plankton in a 63-mile stretch of the Hooghly between Palta and Diamond Harbour were started in 1949 by a team of research workers of the Central Inland Fisheries Research Institute, Barrackpore and the results obtained for the first two years of study have already been published (Dutta *et al.*, 1954). Bose (1956) has given an account of the results obtained by further investigations on the hydrology of a 155-mile stretch of the Hooghly estuary between Nabadwip and Kakdwip. The present paper embodies the results of investigations carried out from July 1956 to December 1958 on the plankton and a few hydrological features of the Hooghly-Matlah estuarine system, including the entire tidal stretch of the Hooghly (a distance of about 185 miles), the Rupnarain estuary and the

upper portion of the Matlah estuary. Description of the physical features of the estuary and its tides and their effects becomes superfluous in view of the detailed account given by the Dutta *et al.* (*op. cit.*). The tidal portions of the Hooghly, the Matlah and Rupnarain estuaries are shown in Text-Fig. 1.



TEXT-FIG. 1. Map of the Hooghly-Matlah estuarine system, showing area of investigation and collection centres.

The analysis of plankton samples was done by the first and second authors, while that of the water samples was done by the third author.

MATERIAL AND METHODS

(*a*) *Centres of Collection*

The plankton and water samples for analyses were collected from nine centres along the Hooghly, 3 centres along the Rupnarain and one centre

along the Matlah (Text-Fig. 1). The entire tidal stretch of the Hooghly was divided roughly into three zones on the basis of salinity distribution. The three zones were termed the upper zone, the middle zone and the lower zone, representing respectively the freshwater zone, the gradient zone, and the tidal and marine zones. Three sampling centres were selected in each zone. The various centres from the upper tidal limit near Nabadwip-Purbasthali area in the north downwards towards the mouth of the estuary were as follows:—

(1) Medgachi, (2) Khasbati and (3) Khusigoli (Zone I—upper zone); (4) Konnagar, (5) Fuleshwar and (6) Diamond Harbour (Zone II—middle zone) and (7) Kakdwip, (8) Namkhana and (9) Frazergunge (Zone III—lower zone) which are located at distances of 163, 132, 126, 108, 79, 50, 25, 16 and 2 miles respectively from the sea face (*i.e.*, from the level of Lower Long Sand Light Vessel).

The river Rupnarain, a tributary of the Hooghly, joins it between Diamond Harbour and Falta and the three sampling centres along its estuarine stretch (Zone IV) were Anantapur, Kolaghat and Gobindapur, located at distances of about 71, 85 and 90 miles respectively from the sea face. The only sampling centre on the Matlah was at its upper stretch at Port Canning (Zone V), which is located at a distance of about 64 miles from the sea face.

During the six months of 1956, samples from the upper and part of the middle zone were collected from centres different from those shown above, but adjacent to them. They were from north to south Nabadwip, Tribeni and Chinsura in the upper zone and Nawabgunge and Uluberia in the middle zone. Collection of samples in Zones III and IV was started only in August 1957 and September 1957 respectively, while in all the other zones the work was initiated in July 1956.

(*b*) *Methods of Collection*

In order to get comparable quantitative values of plankton throughout the period, it is necessary to filter a definite known quantity of water and it is also imperative to filter as large a quantity of water as possible. Earlier method by Roy (1949) consisted of collecting just one-litre samples in a bottle, while that of Dutta *et al.* (*op. cit.*) consisted of collecting surface plankton by conical muslin and organdie nets left in the surface water for five minutes from a stationary boat. While in the former method the quantity of water sampled was too little to be representative, in the latter, the quantity varied according to the speed of the current, with the result the number of plankters computed for any one day was not strictly comparable to that obtained on

any other day. Further, in both the cases the samples were obtained from a restricted area.

The present method was so planned as to overcome the above deficiencies. Fortnightly collections, both at maximum high tide and maximum low tide, were made at each of the 13 sampling centres. In each collection, 150 litres of water in all were collected from the river with a 2-litre mug from a boat moving slowly across the river, taking 50 litres each from the two marginal areas and 50 litres from the central stretch. However, at Diamond Harbour, where the river is too wide (over 15,000 ft.), the collections were made from the eastern margin and the centre only, while in the lower zone the collections were made across the channel creek (Muri Ganga), east of Saugor Island. The water collected was filtered through a plankton net made of bolting silk (No. 25, XXX), having a diameter of $6\frac{1}{2}''$ at its mouth and a filtering surface 9″ long from the ring to the caudal end of the net, to which was attached a wide-calibred tube to receive the plankton. Immediately after collection the plankton was transferred to a bigger tube and preserved in 5% formalin.

Water samples for salinity determination were collected at midstream at fortnightly intervals both during the flood- and ebb-tides in narrow-mouthed reagent bottles. Temperature of the surface water was also noted every time by holding a thermometer in the bottle containing the water sample until a steady temperature was reached. For want of suitable standard equipment in sufficient numbers, only surface collections were made for both the plankton and hydrological studies. In this connection it may be mentioned that Bose (*op. cit.*) has reported the absence of any appreciable thermal and salinity stratification in the Hooghly estuary.

(*c*) *Analysis*

(i) *Salinity.*—Salinity was determined by titrating the sample with silver nitrate, using potassium chromate as indicator.

(ii) *Plankton.*—Each plankton sample was normally made to 150 c.c. and after briskly stirring the sample, a subsample was taken with a wide-bored pipette and transferred to a Sedgwick-Rafter type counting cell, graduated into 1,000 millimeter squares, which when closed with a cover glass held exactly 1 c.c. The plankton contained in this 1 c.c. was the plankton in one litre of river water. In cases where the plankton material in the sample was too scarce or too dense, it was further concentrated or diluted to volumes, which were usually multiples or divisibles of 150 c.c. In every case, a differential count was made of all the plankters, both zoo-and phyto-,

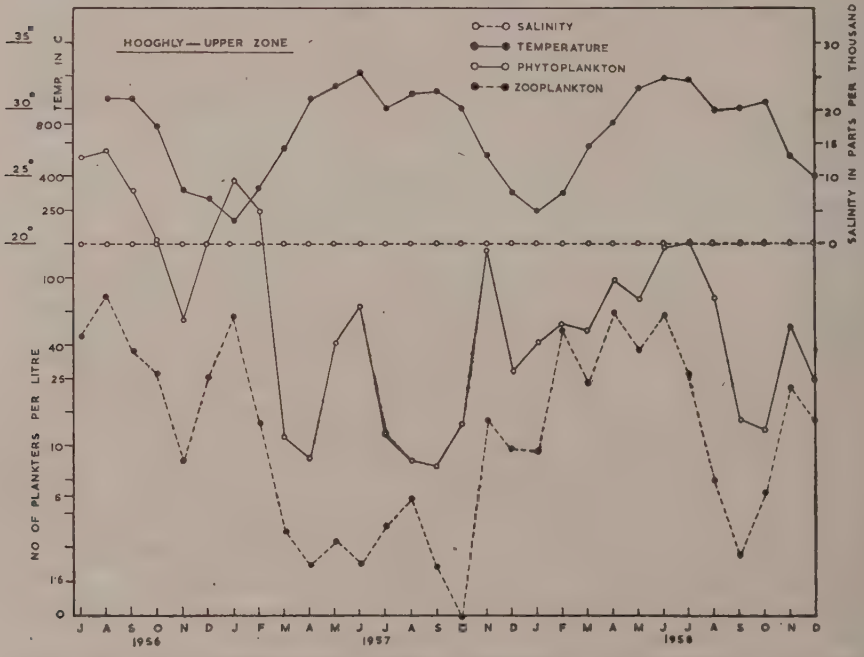
in the the subsample taken in the counting cell and the result expressed as number per litre of water.

Observations

(i) *Hydrology*

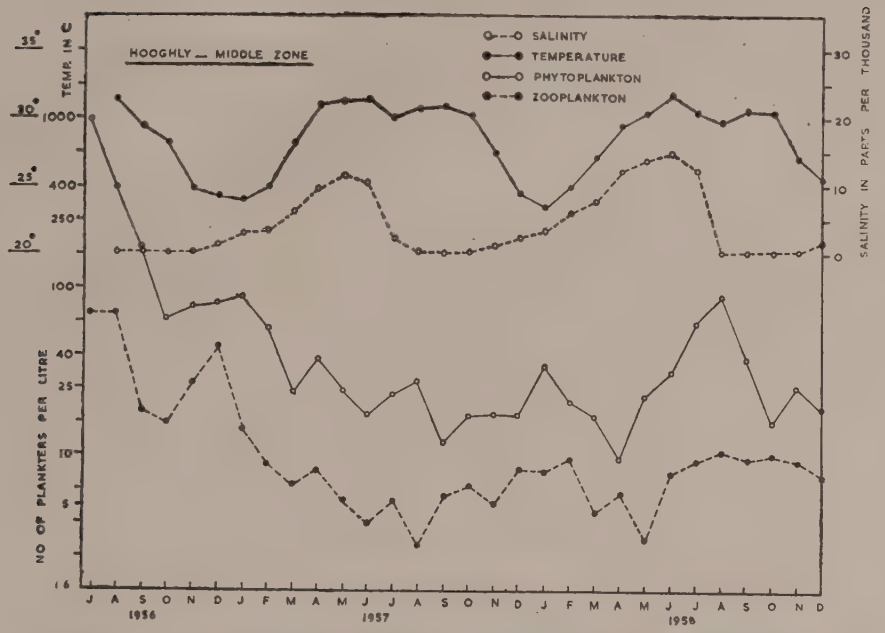
(*a*) *Temperature*

The annual range between maximum and minimum temperatures of surface water in the various zones varied from 7·49–9·42° C. The maximum and minimum recorded during the period of $2\frac{1}{2}$ years were 32·70° C. (in Zone I) and 22·30° C. (in Zone V) respectively. While the upper limits reached during 1957 and 1958 were more or less identical, the minimum temperatures obtained in 1958 were found to be lower than those of 1957.

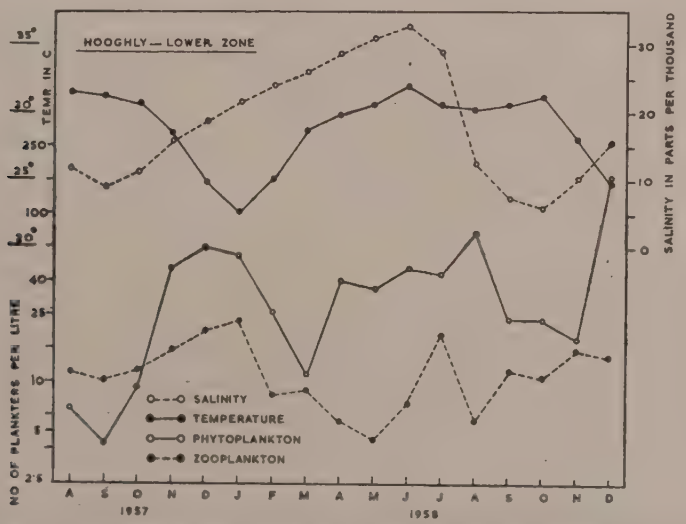

HOOGHLY — UPPER ZONE
SALINITY
TEMPERATURE
PHYTOPLANKTON
ZOOPLANKTON
TEMP. IN C
SALINITY IN PARTS PER THOUSAND
NO OF PLANKTERS PER LITRE
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1956
1957
1958

Text-Fig. 2. The average monthly number of phytoplankton and zooplankton, on a logarithmic scale, and the average monthly surface temperature and surface salinity in Zone I.

In all the zones the temperature shows two peaks, generally one in June and the other in September. While the former constitutes the major peak in the Hooghly and Rupnarain estuaries, in the Matlah the latter forms the major peak. It is further seen that the September temperature is always

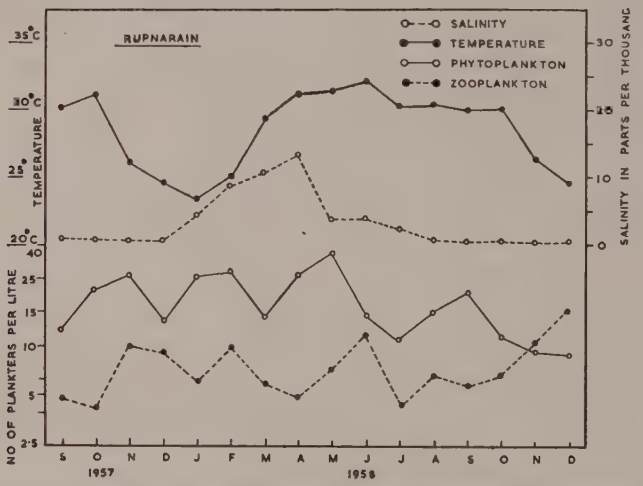

HOOGHLY — MIDDLE ZONE
SALINITY
TEMPERATURE
PHYTOPLANKTON
ZOOPLANKTON
TEMP. IN C
SALINITY IN PARTS PER THOUSAND
NO OF PLANKTERS PER LITRE
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1956
1957
1958

TEXT-FIG. 3. The average monthly number of phytoplankton and zooplankton, on a logarithmic scale, and the average monthly surface temperature and surface salinity in Zone II.



TEXT-FIG. 4. The average monthly number of phytoplankton and zooplankton, on a logarithmic scale, and the average monthly surface temperature and surface salinity in Zone III

higher in the Matlah than in the Hooghly. This may be due to the greater salinity of the Matlah waters (because of the lesser inflow of freshwater into it compared to that of Hooghly), since as stated by Reid (1961), less heat only is required to warm up more saline waters, because with increasing salinity there is a corresponding decrease in specific heat.



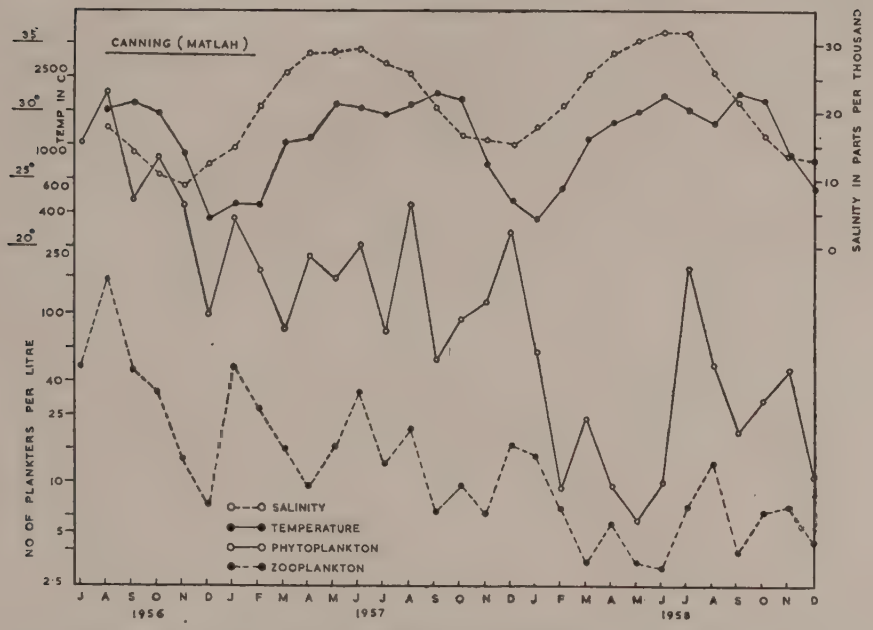
Text-Fig. 5. The average monthly number of phytoplankton and zooplankton, on a logarithmic scale, and the average monthly surface temperature and surface salinity in Zone IV.

December to February may be considered as the low temperature period, with the temperature generally ranging from about 22·0–25·0° C. January constitutes the coldest month of the year. The temperature remains fairly high during April to October, ranging from about 29·0–32·5° C., while it is distinctly less hot during March and November. The fluctuations of temperature, as well as that of salinity in the various zones are plotted in Text-Figs. 2–6.

(*b*) *Salinity*

In general, high salinity values are observed during April–July in both the Hooghly and Matlah estuaries, but in the Rupnarain during March and April. The salinity throughout the year shows only one peak in June in all the Zones, except in zone IV and where it is in April. Thus except in Zone IV, there is a coincidence of the temperature and salinity peaks in June.

The water remains almost fresh throughout the year in the upper zone of the Hooghly. The middle zone represents the gradient zone, with salinity


CANNING (MATLAH)
TEMP IN C°
SALINITY IN PARTS PER THOUSAND
NO OF PLANKTERS PER LITRE
O---O SALINITY
●—● TEMPERATURE
O—O PHYTOPLANKTON
●--● ZOOPLANKTON
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1956
1957
1958

TEXT-FIG. 6. The average monthly number of phytoplankton and zooplankton, on a logarithmic scale, and the average monthly surface temperature and surface salinity in Zone V.

ranging from traces to 15‰. The salinity conditions of the Rupnarain estuary correspond more or less to that of the middle zone of the Hooghly. The Matlah estuary and the lower zone of the Hooghly are much more saline, with the salinity ranging from 9·22–32·08 and 6·18–32·85‰ respectively. The minimum salinity values are obtained during the winter months in the Matlah and during the late monsoon months in the Hooghly and Rupnarain estuaries.

(*c*) *Rainfall*

The average monthly rainfall* (in mm.) in West Bengal, Bihar and Uttar Pradesh, which almost cover the entire catchment area of this estuarine system and its feeder rivers is shown in Table I.

From the above figures it can be seen that the maximum rainfall (about 74–86% of the total) was during June to September in all the years, and this brought about a considerable fall in the salinity of the waters, except in the

* Data obtained from the Regional Meteorological Centres, Calcutta and Delhi.

TABLE I

Average rainfall in mm.

Month	1956	1957	1958
January	14·43	67·89	14·54
February	16·65	10·86	14·83
March	35·47	19·94	12·67
April	17·86	7·36	23·27
May	115·56	15·18	36·52
June	290·23	149·94	112·84
July	294·38	378·81	302·79
August	359·97	284·01	393·32
September	411·48	224·42	383·76
October	173·82	30·05	104·10
November	55·07	1·34	3·95
December	35·51	11·22	6·25

Matlah. However, a noticeable time lag was found between excessive rainfall and depression of salinity, as found in the Tamar estuary by Milne (1938).

(ii) *Distribution and Fluctuations of Plankton Populations*

The study revealed continuous seasonal fluctuations in the plankton populations brought about by the mingling of different kinds of waters and variations in temperature, salinity, turbidity, etc. The monthly average numbers of both total phyto- and zoo-plankton are plotted in Text-Figs. 2–6.

(*a*) *Phytoplankton : General Distribution*

As stated by Roy (1949), the phytoplankton was found to play the main role in determining the pattern of variations in the yield of total plankton. Further, as has been observed previously by Dutta *et al.* (*op. cit.*), the phytoplankton consisted mainly of diatoms throughout the estuarine system all through the year. Among the others, the blue-green algae distinctly predominated in the lower zone of the Hooghly, while the green algae likewise predominated in the Rupnarain estuary. In the remaining zones, the interrelation between these two groups fluctuated throughout the years without any marked definiteness. In the upper zone of the Hooghly the green algae

were found in larger numbers in 1956 and 1958, while in 1957 the blue-green algae were obtained in larger numbers. In the middle zone of the Hooghly the green algae predominated only in 1956, while in 1957 and 1958 the blue-green algae were in slightly greater numbers, the entire algal population during the last two years being rather poor. In the Matlah at Canning the blue-green algae were more abundant in 1956, while the green algae were in larger numbers in 1957. In 1958 the algal population was too poor to give any correct indication of group dominance.

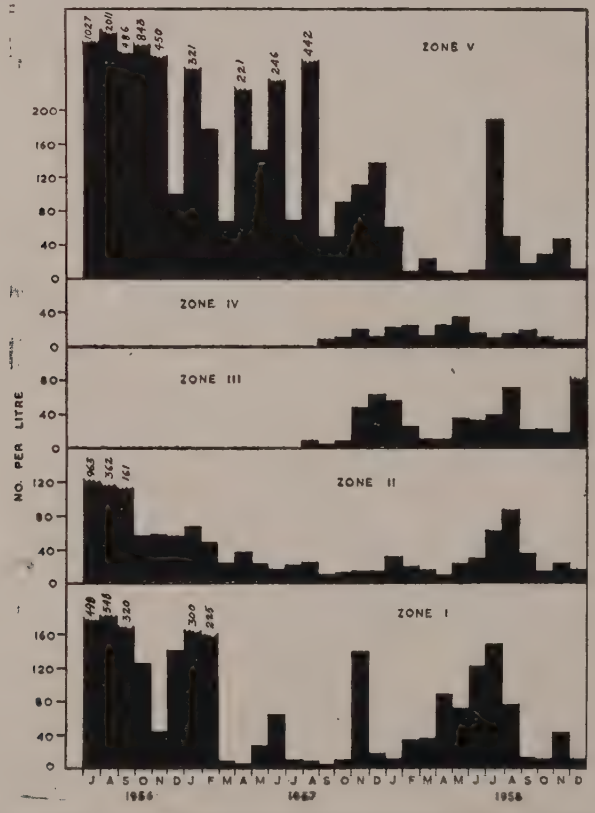
The upper zone of the Hooghly and the Matlah were generally rich in phytoplankton compared to the other zones. Among the two, the Matlah was much richer in 1956 and 1957, while in 1958 its plankton production seemed to have suffered a comparative set-back. The production in the middle zone of the Hooghly and the Rupnarain were more or less of the same magnitude, while it was slightly better in the lower zone of the Hooghly. While freshwater forms predominated in Zone I, the marine forms constituted the bulk in Zones III and V. In the remaining Zones (II and IV) both freshwater and brackish water forms were encountered and even a few marine forms were met with during periods of high salinity.

Fluctuations.—The phytoplankton crop showed, in general, two distinct peaks every year, one during June to August and another during November to January as against the earlier observations of Dutta *et al.*(*op.cit.*) and Roy(1949) of there being only one peak during January. According to Roy (*loc. cit.*) this winter pulse is continuous with "the least significant spring pulse which terminates not later than June or July". However, the relative magnitude of the two peaks observed during the present study varied in different years in the majority of zones and as such it is difficult to name any particular month or season as the most productive in such zones. A steady trend was seen only in Zones III and V. While in Zone III the winter peak (in December) was predominant during both 1957 and 1958, it was the monsoon peak (during August or July) that was of higher magnitude in all the three years in Zone V. Further, the phytoplankton production showed a progressive upward trend in Zone III, while in Zone V it showed a downward trend, specially during 1958. In Zones I and II even though there was no definite trend, the June to August peak was generally found to be of higher magnitude. However, in 1957 in both these zones, the winter peak showed the maximum yield. The trend in Zone IV was a little different from the other zones. In the limited period of observation the highest peak was observed in May and a secondary peak was seen in February. The phytoplankton crop was usually low during September and October and at times during March and April also in almost all the zones. In general, the year

1956 yielded a better crop than the succeeding two years. Diatoms were invariably responsible for all the observed peaks.

The yearly averages and the percentage composition of the main groups of phytoplankton are shown in Table II.*

(1) *Diatoms.*—As observed by Roy (1949), the diatoms were found to play the most important part in determining the pattern of seasonal, as well as annual, variations of phytoplankton in all the zones. Accordingly in keeping with the general trend of the phytoplankton crop, the diatoms were also found in much larger numbers in 1956 than in the succeeding two years. The fluctuation patterns in the average monthly number of diatoms in the various zones are shown in Text-Fig. 7.



TEXT-FIG. 7. Zonewise distribution and monthly fluctuations of average number of diatoms.

* Fungi and bacteria have not been considered in view of their partial retention only by the nets used.

TABLE II

Zonewise yearly average (number per litre) and percentage composition of the main phytoplankton groups

Year		Zone I		Zone II		Zone V		Zone III		Zone IV	
		Yearly average*	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition
1956	Diatoms	278·86	93·60	276·25	94·40	819·75	97·97	×	×	×	×
	Blue-green algae	5·61	1·88	4·87	1·66	12·71	1·52	×	×	×	×
	Green algae	8·91	3·00	10·68	3·65	0·21	0·02	×	×	×	×
	Miscellaneous	4·54	1·52	0·86	0·29	4·12	0·49	×	×	×	×
	Total	297·92	..	292·66	..	836·79	..	×	×	×	×
1957	Diatoms	68·00	82·39	26·10	86·06	173·83	87·33	+	+	+	+
	Blue-green algae	9·23	11·18	2·72	8·97	2·73	1·37	+	+	+	+
	Green algae	4·83	5·85	1·19	3·92	3·44	1·74	+	+	+	+
	Miscellaneous	0·48	0·58	0·32	1·05	19·04	9·56	+	+	+	+
	Total	82·54	..	30·33	..	199·04	..	+	+	+	+
1958	Diatoms	55·48	81·54	30·54	94·91	38·81	97·49	42·78	87·84	17·16	94·50
	Blue-green algae	2·42	3·56	0·92	2·86	0·40	1·00	4·51	9·26	0·26	1·43
	Green algae	10·05	14·77	0·69	2·14	0·27	0·68	0·17	0·35	0·73	4·02
	Miscellaneous	0·09	0·13	0·03	0·09	0·33	0·83	1·24	2·55	0·01	0·05
	Total	68·04	..	32·18	..	39·81	..	48·70	..	18·16	..

* The figures pertaining to 1956 are only half-yearly averages.

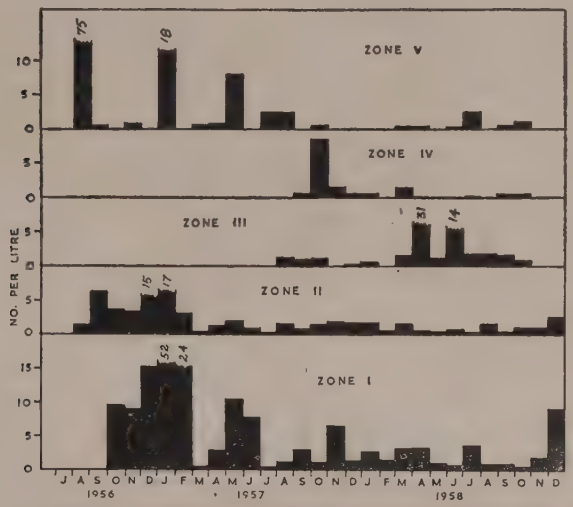
× = Data not collected.

\+ = Data incomplete, hence not included.

In general, the diatom crop shows two peaks one during November to January and the other during June to August and these are responsible for the phytoplankton peaks of the corresponding periods. However, in Zone IV the two peaks were obtained in February and May. Except in Zone III and during 1957 only in Zones I and II, where the winter peaks were more prominent, in all the other zones and during 1956 and 1958 in Zones I and II also, the maximum diatom yield was obtained during May to August. This is contrary to the findings of the previous workers (Dutta *et al.*, *op. cit.* and Roy, 1949), according to whom the maximum yield of diatoms is obtained during the winter months. September to October (except in 1956) and March to April were found to be generally the leanest periods in diatom production.

It was found that different genera or species of diatoms were responsible for the highest peaks in the different years. This conforms to the findings of the previous workers. For example in Zone V *Ditylum brightwellii*, *Coscinodiscus granii*, *C. commutatis* and *Chaetoceros* sp. (with their abundance in the order mentioned) contributed to the highest peak in August 1956, while *Coscinodiscus* sp. and *Biddulphia* spp. were mainly responsible for the highest peaks in 1957 and 1958 in August and July respectively. Similar was the case with the winter peaks in this zone. While *Coscinodiscus* sp. and *Chaetoceros* sp. were responsible for the 1956–57 winter peak, the succeeding winter peak of 1957–58 was brought about by *Biddulphia* spp. Then again *Synedra ulna*, *Melosira* sp. and *Synedra* sp. were respectively responsible for the highest peaks in 1956, 1957 and 1958 in Zone I. Among the others that contributed to the fluctuations in diatom population were *Lithodesmium* sp., *Thalassiothrix* sp., *Pleurosigma* spp., *Nitzschia* sp. and *Rhizosolenia* sp. in Zone V and *Coscinodiscus* spp., *Nitzschia vitrea*, *Navicula* spp. and *Cyclotella* sp. in Zone I. Compared to the above two zones, the others had only a sparser diatom population, especially the Rupnarain estuary. *Coscinodiscus* spp., *Melosira* spp., *Synedra* sp. and *Nitzschia* sp. were mainly responsible for the seasonal variations of diatom population in Zones II and IV. Marine diatoms were found to dominate in Zone III, as in Zone V, the important forms being *Coscinodiscus* spp., *Biddulphia* sp., *Lithodesmium* sp., *Chaetoceros* spp., *Thalassiothrix* sp., *Ditylum brightwellii* and *Pleurosigma* sp.

(2) *Blue-green Algae.*—They were encountered in all the zones (Text-Fig. 8). Though few in number they were found throughout the year in Zones I and II and in the more saline regions they predominated over the green algae. However, their occurrence was more regular in the fershwater



TEXT-FIG. 8. Zonewise distribution and monthly fluctuations of average number of blue-green algae.

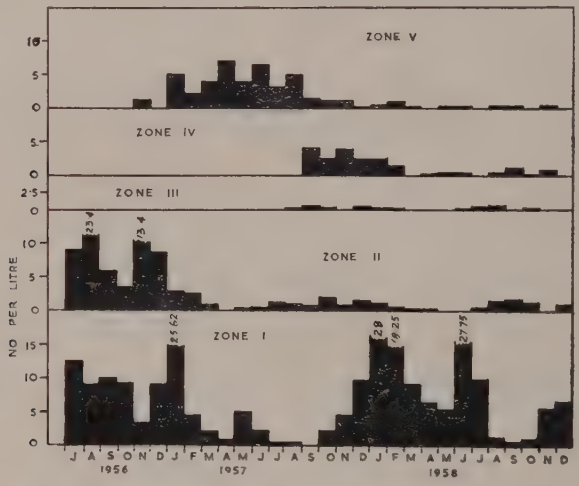
than in the saline regions. In Zones I and II (fresh and brackish water regions) they were maximum during the winter months, while in the more saline Zones III and V the peak was observed during April to June or sometimes during early monsoon in the latter zone. In the Rupnarain, however, the peak was observed in October. Except during 1956 in Zones II and V, the production of blue-green algae in all the zones during the monsoon months was quite poor. Further, in the brackish water Zones II and IV they were seen in much reduced quantities during the summer months also. On the other hand, in the saline Zones III and V, the winter season was generally the poorest.

Species of *Oscillatoria*, *Nostoc*, *Anabaena*, *Phormidium* and *Lyngbya* were observed in all the zones. *Microcystis* spp. and *Trichodesmium* sp. were also common, but they were completely absent from Zones V and I respectively. *Microcystis* colonies and *Phormidium* sp. were found in good numbers only in the upper stretches of the Hooghly in Zones I and II, while *Trichodesmium* sp. was seen in appreciable numbers only in the saline Zones III and V. *Oscillatoria* spp. were, however, found in good numbers in all the zones, except Zone V.

Species of *Phormidium*, *Oscillatoria*, *Microcystis* and *Nostoc* were mainly responsible for determining the seasonal variations of blue-green algae in Zone I. The first two played a similar role in Zone V and the latter two in

Zone II. The single peak observed in Zone III in April 1958 was brought about by *Trichodesmium* sp., while the one observed in October 1957 in Zone IV was due to *Oscillatoria* sp.

(3) *Green Algae*.—These were also found to occur in all the zones, but in appreciable numbers only in the freshwater region (Zone I). However, in 1956 they were present in some numbers in Zone II, but in the succeeding years this zone hardly showed these forms. They were at their minimum in Zone III. In Zone V also they were barely present during 1958 and during the period of observation in 1956 except in November they were completely absent from this zone (Text-Fig. 9).



TEXT-FIG. 9. Zonewise distribution and monthly fluctuations of average number of green algae.

In Zone I, the green algae were found in their maximum numbers in the winter months, with a peak in January. However, in 1958 there was a distinct peak in June also. Two species of *Spirogyra* were mainly responsible for all the peaks in Zones I and II. Species of *Mougeotia*, *Volvox*, *Chlorella* and *Pediastrum* were also seen in good numbers during some of the peak periods. In Zone I the green algae were at their minimum during the monsoon months in 1957 and 1958.

(4) *Miscellaneous*.—This includes the euglenoids, the dinoflagellates and some other holophytic flagellates of doubtful systematic position like the Chrysophyceae. Their occurrence was occasional and in little numbers only. The euglenoids (*Euglena* sp., *Phacus* sp. and *Trachelomonas* sp.) were found

mainly in the freshwater region (Zone I) and to a lesser extent in the brackish water Zones II and IV. On rare occasions *Phacus* sp. and *Euglena* sp. were also encountered in the lower stretches. On the other hand the dinoflagellates *Ceratium* spp., *Peridinium* spp. and *Noctiluca miliaris* were found in significant numbers only in the lower saline regions. The only identified chrysophycean alga, *Dinobryon* sp., was encountered in Zone I.

(*b*) *Zooplankton*

The zooplankton consisted mainly of freshwater and brackish water species in the upper and middle stretches of the Hooghly and the Rupnarain estuary (Zones I, II and IV), while in the lower zone of Hooghly and in the Matlah at Canning (Zones III and V) it consisted essentially of brackish water and marine forms. Copepods constituted the bulk of zooplankton in all the zones almost throughout the year, even though rotifers and larval forms often outnumbered them, and at times were even found in slightly larger quantities. Rotifers, protozoans and cladocerans were found in larger numbers in the less saline areas of upper and middle stretches. Larval forms of several invertebrates, notably those of crustaceans, were found to occur in all the zones.

The production of total zooplankton during the year 1956 was of a much higher magnitude than that of the succeeding two years in all the three zones which were under observation since 1956, except for that of Zone I during the year 1958. In Matlah there was a progressive decline in production from year to year. The range of production in the Hooghly and the Rupnarain during 1957 and 1958 remained more or less at a steady level, except in Zone I, where there was some considerable improvement in 1958 during February to July. Taking the entire period of $2\frac{1}{2}$ years, Zones I and V were found to be the most productive areas.

Fluctuations.—The zooplankton crop also shows two maxima every year, one during November to February and the other during June to August, closely following the phytoplankton maxima. The pattern of fluctuations also is seen to be similar to that of the phytoplankton. Further, here also the relative magnitude of the two peaks varied in the different years and as such there was no clear-cut constant predominance of any month or season. However, it may be mentioned that in Zones III and IV the winter peaks were slightly of a higher magnitude. But in Zone V after the highest peak in

TABLE III

Zonewise yearly average (number per litre) and percentage composition of the main zooplankton groups

Year		Zone I		Zone II		Zone V		Zone III		Zone IV	
		Yearly average*	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition	Yearly average	Percentage composition
1956	Copepods	3·84	10·41	4·89	11·91	12·12	22·80	×	×	×	×
	Cladocerans	0·83	2·25	0·54	1·31	nil	nil	×	×	×	×
	Rotifers	5·07	13·74	6·12	14·90	0·58	1·09	×	×	×	×
	Protozoans	2·87	7·78	1·63	3·97	8·29	15·59	×	×	×	×
	Larvae	4·64	12·57	6·73	16·39	12·96	24·38	×	×	×	×
	Miscellaneous	19·65	53·25	21·16	51·52	19·21	36·14	×	×	×	×
	Total	36·90	..	41·07	..	53·16	..	×	×	×	×
1957	Copepods	3·91	39·61	3·42	49·78	2·54	13·40	+	+	+	+
	Cladocerans	2·90	29·38	0·46	6·69	nil	nil	+	+	+	+
	Rotifers	0·61	6·18	0·32	4·66	1·39	7·33	+	+	+	+
	Protozoans	0·30	3·04	0·15	2·18	1·46	7·70	+	+	+	+
	Larvae	0·74	7·50	0·87	12·66	10·00	52·74	+	+	+	+
	Miscellaneous	1·41	14·29	1·65	24·02	3·57	18·83	+	+	+	+
	Total	9·87	..	6·87	..	18·96	..	+	+	+	+
1958	Copepods	3·49	12·98	2·52	31·61	2·36	34·20	5·67	49·26	4·22	53·56
	Cladocerans	0·43	1·60	0·24	3·01	0·06	0·87	0·04	0·35	0·47	5·96
	Rotifers	11·48	42·71	0·42	5·27	0·23	3·33	0·17	1·48	0·26	3·30
	Protozoans	0·63	2·34	0·45	5·65	0·35	5·07	0·34	2·95	0·37	4·69
	Larvae	8·59	31·96	3·21	40·28	2·90	42·03	4·21	36·58	0·78	9·90
	Miscellaneous	2·26	8·41	1·13	14·18	1·00	14·50	1·08	9·38	1·78	22·59
	Total	26·88	..	7·97	..	6·90	..	11·51	..	7·88	..

* The figures pertaining to 1956 are only half-yearly averages.
x = Data not collected.
\+ = Data incomplete, hence not included.

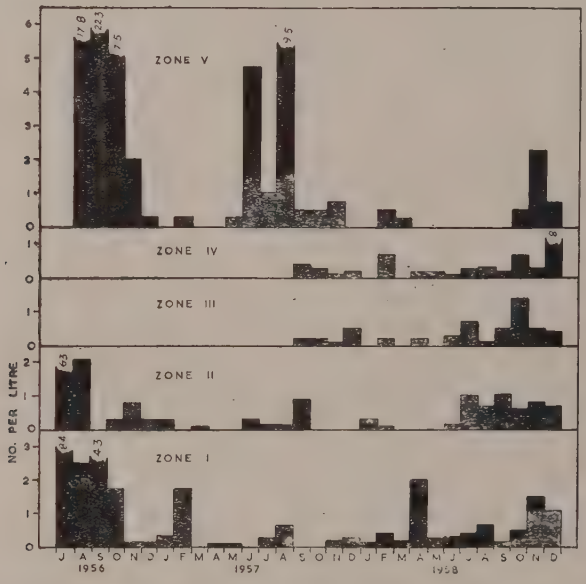
August 1956 there was a progressive downward trend with each successive peak being smaller than the one immediately before it. On the other hand Zone IV showed just the opposite trend. In Zone I after a fairly good crop in 1956, there was a sudden decline in March 1957 and this continued till October 1957. In November there was a sudden improvement, which continued till July 1958. The succeeding monsoon saw another sharp decline in the zooplankton crop, till it improved again in the following winter. Thus the months March to July, which showed the minimum zooplankton crop in 1957, were the most productive in 1958. The late monsoon months were usually the poorest in zooplankton production in most of the areas.

The yearly averages and the percentage composition of the main constituent groups are shown in Table III.

(1) *Protozoa.*—The protozoans were fairly common in most of the zones (Text-Fig. 10), even though they did not form as high a percentage of total zooplankton as recorded by the previous workers. They were found in larger numbers during periods of low salinity in all the zones and showed an increase in quantity upstream, thereby showing an inverse relation with salinity, as observed by Nash (1947) and Dutta *et al.* (*op. cit.*). Except in some areas in 1958, in most of the zones (I, II and V), the protozoans were found in their maximum numbers during July to September, when the water level of the estuary was generally at its maximum and its salinity either the lowest or on the decline. The correlation between water level and protozoan abundance agrees with the observations of Kofoid (1908) and Holden and Green (1960). But according to Dutta *et al.* (*op. cit.*) the period of maximum abundance of protozoans is during November to February. However, that was found to be true only of Zone IV and partly of Zone III. But even here close correlation with salinity of the water could be seen, since the salinity at Zone IV during the winter months continues to be almost as low as that during the late monsoon months. Further, in Zone III the protozoan peak for 1958 is seen in October and this coincides with the lowest salinity period. But this correlation does not hold good in the case of Zone V, where while the winter months constituted the low salinity period, the maximum protozoan crop was obtained during the monsoon months. Further when protozoans did occur, they were found in larger numbers here than in any other zone.

Among the protozoans, the Rhizopoda, specially the testacean rhizopods (*e.g.*, *Difflugia* spp.), were the most common in all the zones. Other

protozoans included Actinopoda (Radiolaria and Heliozoa), tintinnids, *Vorticella*, etc. *Difflugia* spp. were responsible for most of the peaks observed in the various zones, while radiolarians and ciliates and radiolarians were responsible for the peaks in August 1957 and April 1958 in Zones V and I respectively.

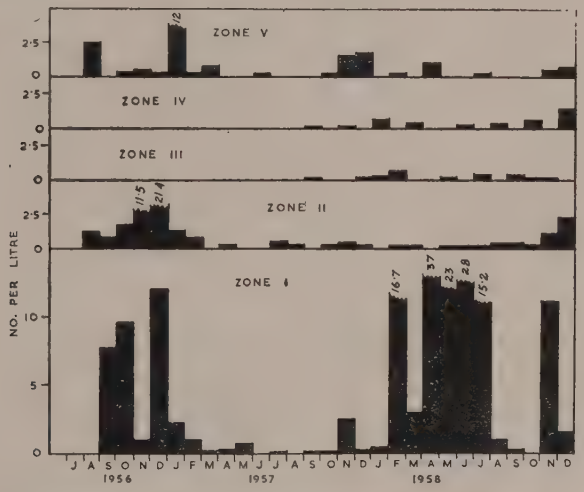


TEXT-FIG. 10. Zonewise distribution and monthly fluctuations of average number of protozoans.

Among the rhizopods, *Difflugia* spp., *Arcella* spp. and Foraminifera were found in all the zones from about June to December. However, *Arcella* spp. were found in appreciable numbers only in Zone I. Some members of the family Euglyphidae were also seen in Zones I and II. Among the Actinopoda, the Heliozoa were observed only in Zone I in February, while the Radiolaria were found during most of the months in all the zones, but essentially in Zones II, III and V. Ciliates were encountered throughout the year in the estuary, their maximum number being in Zone I. Of these *Vorticella* colonies were of common occurrence, while the tintinnids were observed only in the saline Zones III and V from June to November.

(2) *Rotifera*.—The Rotifera, which are more common in freshwaters, showed inverse correlation with salinity and were essentially confined to the freshwater zone (Zone I), even though they were encountered sporadically

in other zones also, specially during low salinity periods in negligible numbers (Text-Fig. 11). Only in the winter of 1956–57 they were seen in appreciable numbers in Zone II (November to December) and to a lesser extent in Zone V (January).



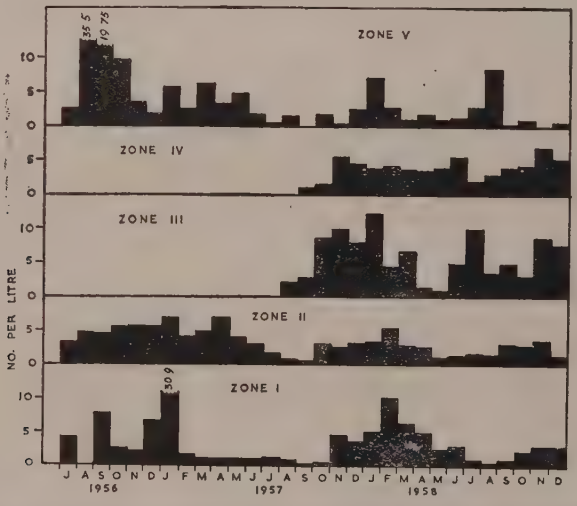
TEXT-FIG. 11. Zonewise distribution and monthly fluctuations of average number of rotifers.

The rotifers were seen in their maximum numbers generally from November to February in all the zones. However, in Zone I during 1958, even though there was a good winter crop, they were at their maximum during April to June with the peak in April and this abundance was the highest for the entire period of two and a half years. During these three months the rotifers dominated the zooplankton population and were present in larger numbers than any other zooplankters. Similar abundance of rotifers in the dry season was observed in river Sokoto by Holden and Green (*op. cit.*). In general, the monsoon months constituted the leanest period of rotifer crop and the same trend was noticed by Holden and Green (*loc. cit.*) in river Sokoto.

Keratella spp., *Brachionus* spp., *Filinia* sp., *Trichocerca* sp. and *Asplanchna* sp. were the common forms, of which the first two were most numerous. *Trochosphaera* sp. and *Tetramastix* sp. were also met with occasionally. Here also it was seen that all the genera were not equally responsible for the annual fluctuations in the yield of rotifers. For instance in Zone I *Brachionus* sp. was dominant during September 1956, while in October it was replaced by *Filinia* sp. The peak obtained in December 1956

was brought about by the combined numbers of *Brachionus* sp., *Trichocerca* sp. and *Asplanchna* sp. *Keratella* sp. was found to be responsible for the peaks in February and April 1958.

(3) *Copepoda*.—As mentioned earlier, the copepods dominated the zooplankton during most of the months in all the zones. They were found in their maximum numbers generally during November to February in Zones I to IV, and during August in Zone V (Text-Fig. 12). A second peak is also seen in July in Zone III and January in Zone V. The maximum density of copepods observed in a single collection was 270 individuals per litre during high tide in January 1957 at Khusigoli (Zone I). In general, the monsoon months were the leanest in copepod production in Zones I, II and IV.



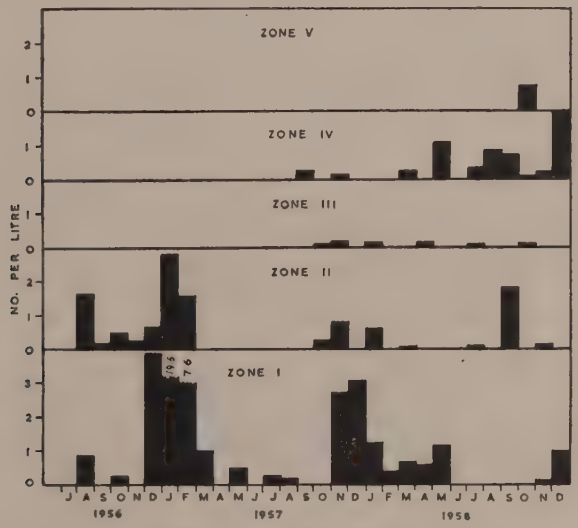
TEXT-FIG. 12. Zonewise distribution and monthly fluctuations of average number of copepods.

Kow (1953) found a direct relation between phytoplankton and copepods in that their peaks coincided. In the present study the copepod peaks were generally found to either coincide with or immediately succeed the winter phytoplankton (as also the diatom) peaks in the Hooghly and Rupnarain and the monooon peaks in the Matlah. According to Nash (*op. cit.*), the copepods increase in quantity downstream and this was found to be substantially true in this estuary also. Further, along the Hooghly, the copepods were found in larger numbers at lower temperatures.

Identification of the various genera and species could not be completed. However, the following genera were recorded from the various zones.

Pseudodiaptomus was present in all the zones, its maximum concentration being in Zone I. *Diaptomus* was observed in appreciable numbers in Zones I and II and a few were also seen in Zone III. The freshwater copepod *Cyclops* was observed only in Zones I and IV, while several unidentified cyclopoids were seen during low salinity periods in other zones as well. Two species of *Acartiella*, *A. tortaniformis* Sewell and *A. major* Sewell were recorded in the brackishwater Zones II and IV. The marine harpacticoid *Microsetella* sp. was present in Zones II, III and V, while another marine form *Paracalanus* sp. was observed in Zones III and IV.

(4) *Cladocera*.—The Cladocera were almost restricted to the fresh and brackish water regions (Zones I, II and IV). In Zone III a few stragglers were found now and then, while in Zone V, except for a few individuals in October 1958, they were completely absent (Text-Fig. 13). They seem to



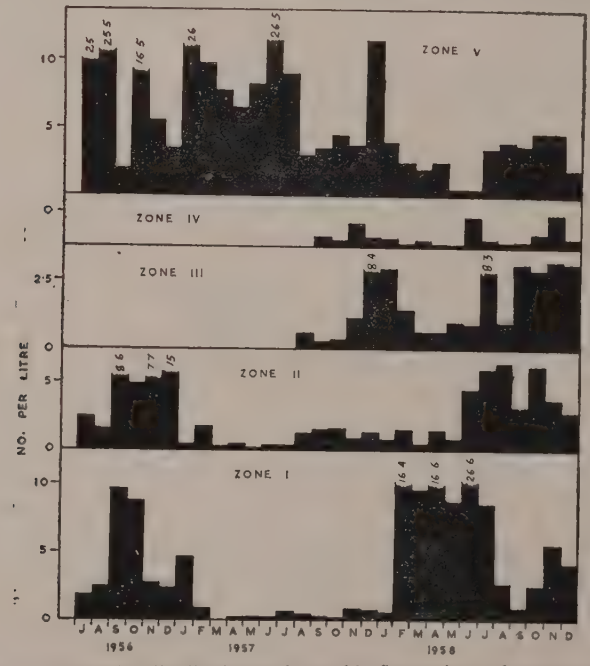
TEXT-FIG. 13. Zonewise distribution and monthly fluctuations of average number of Cladocerans.

bear an inverse relation to temperature in that the maximum numbers were found in the colder months November to February, when in addition to the temperature, the salinity and turbidity of the water were also generally low. They were present in appreciable numbers only in Zone I, the maximum there being obtained during January and February 1957. *Bosmina* sp. was mainly responsible for all the peaks observed in Zone I. In Zone II, in addition to the winter peaks, smaller peaks were obtained in August and Septem-

ber, while generally these monsoon months were the leanest in Zone I. *Bosminopsis* sp. was responsible for the peak in September 1958 in Zone II. While Zone II showed a poor cladoceran crop both during 1957 and 1958, during the latter year Zone IV showed a better crop, which was even better than that of Zone I during the latter half of that year. Except during February and December 1957 in Zone I, the Cladocera never dominated the zooplankton.

Species of *Bosmina*, *Moina* and *Daphnia* were observed in Zones I and II only, while *Ceriodaphnia* sp. and *Bosminopsis* sp. in addition to the above zones occurred also in Zones IV and III respectively. Among the less frequent forms observed were *Holopedium* sp. in Zone I and *Diaphanosoma* sp. in Zone II.

(5) *Larval Forms*.—Larval forms of several invertebrates were observed in all the zones practically throughout the year, occurring in appreciable numbers during certain seasons, except in Zone IV. Zone V showed the maximum larval population in 1956 and 1957, while in 1958 the maximum abundance was in Zone I. In general, the larval population showed two



TEXT-FIG. 14. Zonewise distribution and monthly fluctuations of average number of larva-forms.

peaks, one during November to February and the other during June to September (Text-Fig. 14). The time of maximum abundance of the larvae, which mostly consisted of copepod nauplii, either coincides or immediately succeeds or precedes the copepod peaks. This agrees partly with the observations of Holden and Green (*op. cit.*) and Kofoid (*op. cit.*) and partly with that of Cohn (1903). Further the larval peaks were also found more or less to coincide with those of the total phytoplankton, as well as of the diatoms. Prasad (1954) found similar relation in the sea off Mandapam.

In both the Zones I and II, the larvae were found in their minimum numbers in 1957, while in Zone V, 1958 was comparatively poorer than the preceding years. In Zone I, the June to September peak was found to be of greater magnitude, while in other zones the relative magnitude of the two peaks varied in different years.

Nauplii and Larval Peaks.—Among the larvae, the crustacean nauplii were the most dominant, except at Zone IV and during periods of extreme abundance of megalopa larvae. In fact they were mainly or almost wholly responsible for most of the observed larval peaks, except at Zone IV. Their relative predominance was most conspicuous in Zone I, where during the six months of 1956 the larval population consisted almost exclusively of nauplii, there being in some collections as many as 80 per litre.

Megalopa Larvae.—Varying numbers of the megalopa of *Varuna litterrata* were found in the various zones during June to December. They were, however, found in their maximum numbers only during July to September, especially at Zones IV and V. During the period of their maximum abundance they literally clogged the net and were easily the most prominent plankton element. It is surprising that they were completely absent during 1956 in all the three zones then under observation. During the succeeding years also their number continued to be poor in Zone I, while at Zone II they were found in large numbers only at Konnagar during August and September and in Zone III only at Frazergunge during July. Zones IV and V showed a very dense megalopa population during August, with their number up to 1673 and 1207 respectively in 150 litres of river water.

Veliger Larvae.—Even though, not usually in large numbers, lamellibranch and gastropod veligers were of common occurrence in all the zones during most of the months. In Zones I and II the lamellibranch veligers were more common, being present practically all through the year, while in the remaining zones both kinds of veligers were equally common, their occurrence being spread over fewer months than in Zones I and II. In Zone IV

the veligers, mostly of lamellibranchs, often dominated the zooplankton and of the three peaks observed in that region, they were solely responsible for two in November 1957 and June 1958 and were also partly responsible for the third peak in November 1958. Similar dominance of gastropod veligers was observed during July 1956 in Zone I.

In addition to the above, one Echinospira larva (a modified veliger) was recorded at Konnagar in Zone II in July 1957 and a few Glochidium larvae of lamellibranchs were also observed in Zones I and V during June and September respectively.

Annelid Larvae.—These were of common occurrence only in Zone V, where they were found during May to December, and to a lesser extent in Zone II from April to August and November to December. They were also seen during June, August and November at Zone III. They were practically absent from Zones I and IV, except for a single trochophore larva observed once in each place.

Among these larval forms, the trochophore larva was the commonest. It was observed at Zone V from May to August and in December, and at Zone II from June to August. All those observed at Zone III were trochophore larvae. Mitraria larva was seen at Zone V during September and December. Post-trochophore stages, like nectochaete and spionid larvae, were of common occurrence in Zones II and V.

Among other larval forms, Cyphonautes was frequently observed at Zone III from November to May and at Zone V from December to February and in August. Stray individuals were also recorded at Zone II during February and October. Larvae of rarer occurrence included zoea larvae in Zones III and V, ophiopluteus in Zone V in October and February, amphiblastula larva of sponge during January in Zone V and July in Zone III, furcilia stage of an euphausiid during July 1958 at Frazergunge in Zone III, larvae of the mysid *Mesopodopsis orientalis* during July in Zone I, insect larvae in Zones I and II and cladoceran embryos in Zone I. A few larvae of gobiids, *Coilia* spp., *Pama pama*, *Sciaena* sp., *Mugil parsia*, etc., were also noticed in the collections.

(6) *Miscellaneous.*—Under this are included all other forms of rare or sporadic occurrence. Among the crustaceans, the amphipods were seen only in Zone I in April, while the ostracods were more widespread, being found in Zones I, II, IV and V. A few isopods were also seen in Zones I, II and IV, of which the one observed at Zone I was found to belong to the family Cirolanidae. *Sagitta* spp. were commonly seen almost throughout

the year at Zone III and a few were also observed at Zones II, IV and V. Among the others may be mentioned the water mites (all zones), nereid worms (Zone II), nematodes (Zones II to V), gemmules of sponge (Zone V), bivalves (Zones II and IV) and hydrozoan medusae (Zone II). A large concentration of the mysid, *Mesopodopsis orientalis* was observed during July 1957 at Khasbati in Zone I.

Discussion

It is well known that the production, composition and distribution of plankton is governed by several hydrological features like salinity, temperature, turbidity, dissolved oxygen and nutrients like phosphates, silicates, etc. As stated by Reid (*op. cit.*), "the successful development and maintenance of a population depend upon harmonious ecological balance between environmental conditions and tolerance of the organisms to variations in one or more of these conditions". Of the various factors the present study has covered only salinity, temperature and rainfall.

Temperature.—Temperature is known to play an important part in determining the fluctuations in plankton populations and their distribution. The rate of metabolism and hence the rate of growth and reproduction of any given species is regulated by temperature (Sverdrup *et al.*, 1942). McCombie (1953) suggested that phytoplankton cycles were basically controlled by water temperatures, but that the effects of this control might be obscured by local weather and/or nutrient supply. Each organism is known to have its minimum, optimum and maximum limits of temperature tolerance and according to Roy (1955) the low winter temperature in the Hooghly is favourable for the growth of a large number of diatoms resulting in the highest plankton peak in the year. A similar opinion was also expressed by Dutta *et al.* (*op. cit.*). However, the present investigation has shown a second diatom peak during June to August, when the temperature is relatively high (about 30° C.) and this peak was often the highest peak in the year. This must be due partly to those diatoms thriving in higher temperatures like *Synedra ulna*, *Ditylum brightwellii*, *Coscinodiscus granii*, etc. Partly it may also be due to the availability of abundant nutrient supply during this period (Roy, 1955) and to the physiological state of several organisms, wherein a drop in salinity of the water, as usually happens during this period, is believed to induce them to undergo sexual reproduction, which rejuvenates the individuals and leads to a rapid increase in the population (Subramanyan, 1959 *a*).

Among the diatoms thriving well in the low temperatures may be mentioned certain species of *Melosira*, *Coscinodiscus*, *Chaetoceros* and *Biddulphia*. *Synedra* spp. were found in their largest numbers during high temperature periods (July to August), as against Roy's (1955) observation of there being no correlation between *Synedra* and temperature. Further his observation that *Coscinodiscus* showed an inverse relation of yield with temperature within 20·0–31·5° C. cannot at least be true of all its species, since some species were found in their largest numbers during periods of high temperature. Different species of *Biddulphia* and *Chaetoceros* were found to thrive both in low and high temperature periods.

The low temperature seems to be favourable for most of the green algae (Chlorophyceae), some blue-green algae like *Microcystis* sp., *Nostoc* sp. and also certain species of *Phormidium* and *Oscillatoria*. However, certain other species of *Phormidium* and *Oscillatoria*, and *Trichodesmium* sp. attained their maxima during high temperature periods.

Among the zooplankters, a great majority of the rotifers and cladocerans seem to bear an inverse relation to temperature, within certain limits, in that they attain their maxima during the winter months. However, different species of the rotifers *Keratella* and *Brachionus* showed a wide range of optimum temperature, namely 23·8–32·4° C. and 23·4–30·7 ° C. respectively. On the other hand, the cladoceran *Bosminopsis* was found to thrive well only in higher temperatures (about 30° C.). Along the Hooghly the copepods were found in larger numbers at lower temperatures. The protozoans, on the other hand, do not seem to be conditioned in their yield by temperature.

The comparatively low production in November to December of both phyto- and zoo-plankton in Zones I and II in 1958 was probably due to the relatively high temperature that prevailed during that period, since increase in temperature is believed to exert a negative effect on the phytoplankton, because increased respiration uses up part of the store of energy that would otherwise be used in the production of new plant material (Riley, 1946).

Salinity.—An exact knowledge of the distribution of salt-water in the estuary and the extent of its variability is of importance in that it is one of the main factors influencing the distribution of animals and plants (Alexander *et al.*, 1935). As stated by Reid (*op. cit.*), salinity is an environmental factor, which limits organisms, primarily by interactions with physiological processes other than the uptake and utilization of nutrients. The variations in salinity operate mainly as a selective agency determining the composition or types of species that make up the population rather than on the fertility

of the region (Sverdrup *et al.*, *op. cit.*). The fall in salinity in the lower stretches of this estuarine system has been found to result in the appearance of some freshwater forms there, while conversely in the upper reaches with the rise in salinity some marine forms could be found, as was seen in the Rupnarain estuary during the summer months. Salinity was found to bear an inverse relation to and restricted the distribution of rotifers, cladocerans, green algae and many protozoans mostly to the upper stretches.

A progressive increase in average annual salinity from 1956–58 was noticed in Zones II and V, while in Zone III there was a fall in average salinity during 1958 over that of 1957. According to Nash (*op. cit.*) salinity is related inversely to turbidity and directly to the depth of light penetration, and as such increase in salinity should promote greater production of plankton and *vice versa*. But such a correlation was not noticed in the present study, except in Zone II. However, with the increase in yearly average of salinity, there was a corresponding increase of diatom-percentage in the annual average of total phytoplankton yield, though not in the absolute quantity of the diatoms, as found by Roy (1955). Roy's (1955) statement that the seasonal changes of salinity were inversely correlated with phytoplankton yield does not seem to be tenable, inasmuch as one of the two phytoplankton peaks of the year was sometimes obtained during high salinity periods.

Rainfall.—According to Roy (1949), the total annual rainfall has a distinct "reverse relation" with the average annual yield of the plankton. From the present study it was found that of the three zones (I, II and V) for which full data could be obtained for the years 1957 and 1958, the above correlation could be seen only in the Matlah estuary (Zone V), while along the Hooghly (Zones I and II) the average annual yield of the plankton remained more or less at the same level, in spite of the increased rainfall during 1958. Roy (*loc. cit.*) further states that the total plankton or phytoplankton yield is found to be much reduced during the monsoon. This was found to be true of the late monsoon months in all the zones. This is probably due to the diluting effect of the rains both on the plankton and on nutrient salts, as pointed out by Holden and Green (*op. cit.*). But during the earlier part of the monsoon there was often a good crop of plankton as pointed out earlier. Whether this plankton bloom is induced by the rainfall (Muthu, 1955) or by the drop in salinity (Subramanyan, 1959 *a*), it is difficult to determine. The abundance of protozoans during the monsoon months July to September must be due to the rising river flushing out rhizopods from swampy heavily vegetated areas, as found by Holden and Green (*op. cit.*)

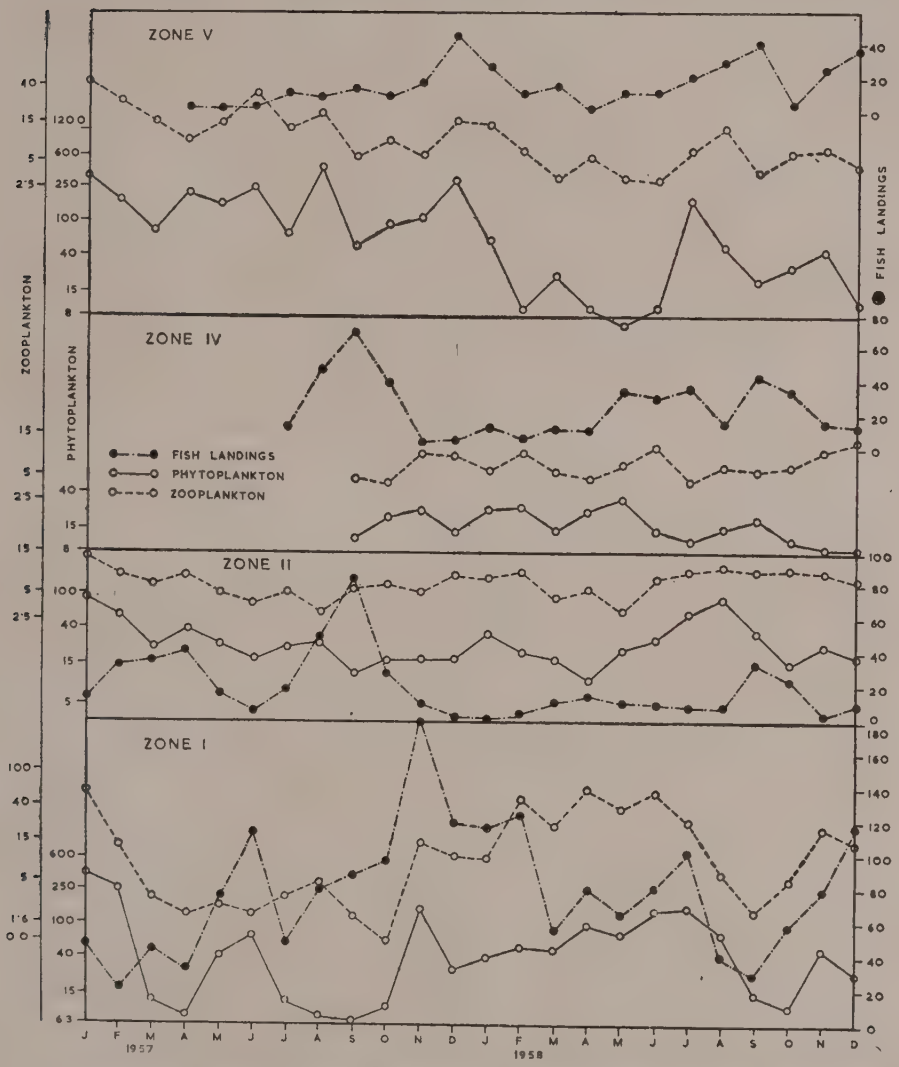
in river Sokoto. That the density of protozoan population is more dependent on river level than low salinity is evident in the Matlah estuary, where while the winter months constituted the low salinity period, the maximum protozoan crop was obtained during the monsoon months. Roy's (1955) statement that apparently no correlation exists between turbidity range and the holozoic protozoan yield lends further support to the above view.

Phytoplankton-Zooplankton Relationship.—Theoretically the phytoplankton peaks should be followed by the zooplankton peaks, since the former serves as food for the latter. However, it was found that this was not always the case and quite often the two peaks were found to coincide thereby showing direct relation. At other times, they showed an inverse relation and this feature has been adequately accounted for by three different theories, *viz.*, (1) the theory of grazing (Harvey *et al.*, 1935), (2) the theory of animal exclusion (Hardy and Gunther, 1935) and (3) the theory of differential growth rate (Steemann Nielsen, 1937), any or each of which partly might be valid for the observed effects in the present study. Tidal currents and vertical turbulence might also be partly responsible for this negative correlation (Riley and Bumpus, 1946).

The relation between diatoms and total phytoplankton on the one hand and the copepods and the larvae on the other has already been discussed above in an earlier section.

Correlation between Plankton Production and Fisheries.—Since the young of almost all fishes and many adults feed on plankton, often a direct relation is seen between the density of plankton and the density of plankton-feeding fish and their predators or total fish landings, as has been shown by the work of several investigators like Hardy *et al.* (1936), Chidambaram and Menon (1945), Prasad (1954 *a*), Subramanyan (1959), etc.

In Text-Fig. 15 are shown the monthly total commercial fish landings during the years 1957 and 1958 from Zones I, II, IV and V, along with the monthly averages of total phyto- and zoo-plankton. It can be seen from this figure that in Zones I and V there is apparently a direct relation between the total fish landings and the plankton population, specially the phytoplankton. A somewhat similar but less clear relation is seen in Zones II and IV also during 1958. The apparently inverse relation during September 1957 in Zones II and IV, when the fish landings reached their maximum without any corresponding increase in plankton production, must be due to the heavy landings of the non-feeding mature Hilsa. In Zone III the plankton yield reaches its maximum during the winter months and this probably is



TEXT-FIG. 15. Zonewise monthly fluctuations of average number of phytoplankton and zooplankton, on a logarithmic scale, and the total fish landings in metric tonnes.

one of the principal factors responsible for the heavy winter catches in that zone. An examination of the bag net catches, consisting mostly of small-sized fishes and prawns, which primarily subsist on plankton, also shows direct relation with plankton peaks in Zones I and V. However, these

apparent relations cannot be relied upon fully, in view of the fluctuations in fishing effort.

In conclusion, as observed by Lewis (1929) "by learning the relation of the fish to its food environment, it may become possible by examinations of fluctuations in the quantity of fish food, to evaluate the significance of one of those factors that determine in advance the relative abundance of fish for certain year classes", and also to determine the cause for the apparent migration of certain fish.

Summary

The distribution and seasonal fluctuations of plankton and a few hydrological and meteorological features in the Hooghly-Matlah estuarine system were studied for a period of two and a half years from July 1956 to December 1958.

The general trend of fluctuations of surface temperature and surface salinity was found to be similar in all the years. The temperature showed two peaks usually one in June and the other in September. The annual range between maximum and minimum temperatures in the various zones varied from 7·49–9·42° C. High salinity values were obtained from April to July in the Hooghly and Matlah estuaries and during March and April in the Rupnarain estuary, with the peaks during June and April respectively. Average annual salinity showed progressive increase in Zones II and V, and a fall during 1958 over that of 1957 in Zone III. About 80% of the total rainfall was obtained during the months June to September.

The plankton crop was of a higher magnitude in 1956 than in the succeeding years. Seasonal fluctuations of the main constituent groups of both phytoplankton and zooplankton have been fully described. Both the groups showed a bimodal cycle, with one peak during June to August and the other during November to January, with the latter period extending to February in the case of zooplankton. They were generally at their lowest level during the late monsoon months. Diatoms and copepods were found to dominate the phytoplankton and zooplankton cycles respectively. Zones I and V were the most productive.

The probable effects of temperature, salinity and rainfall on plankton production have been discussed, as also the phytoplankton-zooplankton relationships. Temperature was found to influence the quantitative fluctuations of plankton, while salinity largely determined its composition and distribution.

An apparent direct relation was noticed between plankton production and commercial fish landings.

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APPENDIX

List of identified plankters and their zonewise distribution

('x' = Present, .. = Absent)

	Zones				
	I	II	III	IV	V
(*a*) Diatoms					
1. *Synedra ulna* ..	x	x	x	x	x
2. *Coscinodiscus granii* ..	x	x	x	x	x
3. *C. radiatus* ..	..	x	..	..	x
4. *C. commutatis* ..	..	..	x	..	x
5. *C.* spp. ..	x	x	x	x	x
6. *Surirella elegans* ..	x	x	x	x	x
7. *Melosira granulata* ..	x	x	x	x	x
8. *M.* spp. ..	x	x	x	x	x
9. *Nitzschia vitrea* ..	x	x	x	x	x
10. *Navicula* spp. ..	x	x	x	x	..
11. *Pleurosigma* spp. ..	x	x	x	x	x
12. *P. elongata* ..	..	..	..	..	x
13. *Amphora* sp. ..	x	x	..	..	x
14. *Climacodium* sp. ..	x	x	x	..	x
15. *Asterionella japonica* ..	x	x	x	..	..
16. *Stephanodiscus* sp. ..	x	x	x	x	x
17. *Cyclotella* spp. ..	x	x	x	x	x
18. *Cymbella cistula* ..	x	x	x	x	..
19. *Chaetoceros* spp. ..	x	x	x	x	x
20. *Diploneis* sp. ..	x	x	x	x	..
21. *Biddulphia mobiliensis*	x	x	x	x	x
22. *Bacillaria paradoxa* ..	x	x	x	..	x
23. *Mastogloea* sp. ..	x	..	..	x	..
24. *Meridion* sp. ..	x	x	..	..	x
25. *Planktoniella sol* ..	x	..	x	..	x
26. *Lithodesmium* spp. ..	x	x	x	x	x
27. *Thalassiothrix longissima* ..	x	x	x	x	x

	Zones				
	I	II	III	IV	V
(*a*) Diatoms (*Contd.*)					
28. *Ditylum brightwellii* ..	x	x	x	x	x
29. *Rhopalodia* sp. ..	x	x	..	..	..
30. *Gomphonema* sp. ..	x	..	..	x	..
31. *Diatoma* sp. ..	x	..	x	..	x
32. *Eucampia* sp. ..	..	x	x	..	x
33. *Actinocyclus* sp. ..	x	x	..	..	x
34. *Hemidiscus hardmannianus* ..		x	x	..	..
35. *Hemiaulus sinensis* ..	..	x	x	..	x
36. *Sceletonema costatum*	..	x	..	..	x
37. *Triceratium* sp. ..	..	x	x	..	x
38. *Epithemia* sp. ..	..	x	..	..	..
39. *Rhaphoneis* sp. ..	..	x	..	..	..
40. *Gyrosigma* spp. ..	..	x	x	x	x
41. *Rhizosolenia* spp. ..	..	..	x	..	x
42. *Bacteriastrum* spp. ..	..	..	x	..	x
43. *Lauderia* sp. ..	..	..	x	..	x
44. *Cocconeis* sp. ..	..	..	x	..	x
45. *Cerataulina* sp. ..	..	..	x	..	..
46. *Thalassionema* sp. ..	..	..	..	..	x
47. *Thallasiosira marginata*	..	..	..	..	x
48. *Aulacodiscus* sp. ..	x	x	x	..	x
49. *Fragilaria* sp. ..	x	x	..	..	x
50. *Pinnularia gibba* ..	x	x	..	..	..
(*b*) Green Algae					
1. *Pediastrum simplex* ..	x	x	..	..	..
2. *P.* spp. ..	x	x	x	x	..
3. *Mougeotia* sp. ..	x	x	..	..	..
4. *Closterium* sp. ..	x	x	x	..	x
5. *Ankistrodesmus* sp. ..	x	x	..	..	x
6. *Cosmarium* sp. ..	x	..	..	..	..
7. *Spirogyra* spp. ..	x	x	x	x	x
8. *Eudorina elegans* ..	x	x	..	..	..
9. *Pleodorina* sp. ..	x	..	..	..	..
10. *Actinastrum* sp. ..	x	..	..	..	..
11. *Tribonema* sp. ..	x	..	x	x	..

	Zones				
	I	II	III	IV	V
(*b*) Green Algae (*Contd.*)					
12. *Euastrum* sp. ..	x	..	..	..	..
13. *Chlorella* sp. ..	x	x	..	..	..
14. *Scenedesmus quadricauda* ..	x	x	..	x	..
15. *Zygnema* sp. ..	x	..	..	..	..
16. *Desmidium* sp. ..	x	x	x	x	x
17. *Pandorina morum* ..	x	x	..	x	..
18. *Platydorina caudatum*	x	..	..	..	..
19. *Borgea planktonica* (?)	x	x	x	x	x
20. *Treubaria* sp. ..	x	..	..	..	..
21. *Chlorococcus* sp. ..	x	x	..	..	..
22. *Closteriopsis* sp. ..	..	x	..	x	x
23. *Staurastrum* sp. ..	x	..	..	..	..
24. *Oedogonium* sp. ..	..	x	..	..	..
25. *Ulothrix* sp. ..	x	..	..	x	..
26. *Micrasterias* sp. ..	..	..	..	x	..
27. *Microspora* sp. ..	..	x	..	..	..
28. *Volvox* sp. ..	x	x	..	..	..
29. *Coelastrum* sp. ..	x	..	..	..	..
30. *Kirchneriella* sp. ..	x	..	..	..	..
(*c*) Blue-green Algae					
1. *Microcystis* spp. ..	x	x	..	x	..
2. *Phormidium* spp. ..	x	x	x	..	x
3. *Nostoc* spp. ..	x	x	x	x	x
4. *Oscillatoria* spp. ..	x	x	x	x	x
5. *Anabaena* spp. ..	x	x	x	x	x
6. *Nostochopsis* sp. ..	x	..	x	..	..
7. *Gloeotrichia* sp. ..	x	x	..	..	..
8. *Aphanizomenon* sp. ..	x	x	..	x	..
9. *Cylindrospermum* sp.	x	..	..	..	..
10. *Merismopedia* sp. ..	x	..	..	..	..
11. *Spirulina major* ..	x	x	..	..	..
12. *Lyngbya* sp. ..	x	x	x	x	x
13. *Aphanocapsa* sp. ..	x	..	..	..	..
14. *Coelosphaerium* sp. ..	x	..	..	..	..

	Zones				
	I	II	III	IV	V
(*c*) Blue-green Algae (*Contd.*)					
15. *Plectonema* sp.	..	x	..	..	..
16. *Trichodesmium* sp.	..	x	x	x	x
17. *Rhizoclonium* sp.	x	..	..	..	..
18. *Wollea* sp.	x	..	..	..	..
(*d*) Flagellates					
1. *Euglena* sp.	x	x	x	..	..
2. *Dinobryon* sp.	x	x	..	..	..
3. *Ceratium hirudinella*	x	x	x	x	x
4. *C. tripos*	..	x	x	..	x
5. *Phacus* sp.	x	x	x	x	x
6. *Peridinium* spp.	x	x	x	..	x
7. *Noctiluca miliaris*	x	..	x	x	x
8. *Trachelomonas* sp.	x	..	..	x	..
(*e*) Protozoa					
1. *Difflugia* spp.	x	x	x	x	x
2. *Arcella* spp.	x	x	x	x	x
3. *Bursaria* sp.	x	x	..	..	..
4. *Vorticella* sp.	x	x	..	x	x
5. *Nuclearia* sp. (?)	x	..	..	..	..
6. *Centropyxis* sp.	..	x	..	x	x
7. *Proteomyxa* sp.	..	x	..	..	..
8. *Tintinnidium* sp.	..	..	x	..	x
9. *Globigerina* sp.	..	..	..	x	..
(*f*) Rotifera					
1. *Brachionus* spp.	x	x	..	x	x
2. *Keratella* spp.	x	x	..	x	..
3. *Trochosphaera* sp.	x	..	..	..	..
4. *Tetramastix* sp.	x	..	..	..	..
5. *Trichocerca* sp.	x	..	..	..	..
6. *Asplanchna* sp.	x	..	..	..	x
7. *Filinia* sp.	x	x	..	..	..
8. *Hexarthra* sp.	x	..	..	..	..
9. *Notholca* sp.	..	..	x	..	..
10. *Ploesoma* sp.	..	..	..	x	..

	Zones				
	I	II	III	IV	V
(*g*) Copepoda					
1. *Pseudodiaptomus* spp.	x	x	x	x	x
2. *Diaptomus* spp. ..	x	x	x	..	..
3. *Microsetella* sp. ..	..	x	x	..	x
4. *Acartiella tortaniformis*	..	x	..	x	..
5. *A. major* ..	..	x	..	x	..
6. *Paracalanus* sp. ..	..	..	x	x	..
7. *Cyclops* sp. ..	x	..	..	x	x
(*h*) Cladocera					
1. *Bosmina* sp. ..	x	x	..	..	..
2. *Bosminopsis* sp. ..	x	x	x	..	..
3. *Ceriodaphnia* sp. ..	x	x	..	x	..
4. *Daphnia* sp. ..	x	x	..	..	..
5. *Holopedium* sp. (?) ..	x	..	..	..	..
6. *Moina* sp. ..	x	x	..	..	..
7. *Diaphanosoma* sp. ..	..	x	..	..	..
(*i*) Miscellaneous					
1. *Mesopodopsis orientalis*	x	..	..	..	..
2. *Sagitta* sp. ..	..	x	x	x	x

OBSERVATIONS ON THE CHAETOGNATHA OF THE WATERS AROUND MANDAPAM

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(Central Marine Fisheries Research Institute)

Introduction

Different species of organisms belonging to diverse groups like diatoms, medusae, pteropods, chaetognaths and tunicates that occur in the plankton are known to be indicators of the water-masses and changing hydrological conditions and of those, chaetognaths have been successfully used in many regions during recent times. Further, the chaetognaths take their place in the food cycle of the sea as predators, competitors and prey in relation to the other constituents of the marine animal community and hence the importance of their study cannot be overemphasised.

Ever since the classical work of Russell (1935 and 1939) on the chaetognaths of the English Channel and the North Sea and their use as indicators of the movements of water masses in that region, the study of chaetognaths has assumed considerable importance. Special mention may be made to the works of Tokioka (1940), Clarke *et al.* (1943), Thomson (1947), Pierce (1953), Bieri (1959), Heydorn (1959) and Sund (1959) outside India.

Though our knowledge of the systematics and distribution of the Chaetognatha of the Indian waters is by no means extensive, there have been useful contributions by workers from different parts of the country. John (1933 and 1937) gave an account of the systematics and distribution of *Sagitta* from the Madras coast. Lele and Gae (1936) recorded three species of *Sagitta* from the Bombay Harbour. Subramaniyam (1937) critically reviewed John's work and in 1940 recorded *S. bedoti* Beraneck from the same collections. Varadarajan and Chacko (1943) and Chacko (1950) worked on the arrow-worms of Krusadai and recorded *Spadella cephaloptera* and *Krohnitta pacifica* for the first time from Indian waters. George (1952) gave a detailed account of the systematics of the Chaetognatha of the Indian coastal waters and the seasonal distribution of the different species along the Malabar coast in relation to the prevailing hydrographical conditions. Ganapati and Rao (1954), Rao (1958 *a* and *b*) and Rao and Ganapati (1958) made investigations on the systematics and distribution of the Chaetognatha

off Visakhapatnam coast and discussed their value as indicators off that coast.

The present paper gives an account of the seasonal changes in the abundance of chaetognaths of Mandapam waters with a comparison of their occurrence in the Gulf of Mannar and Palk Bay. An attempt is made to correlate the seasonal fluctuations of the different species with the changes in the salinity and temperature of the surface waters and other environmental factors.

Mandapam lies at 9° 16′ N and 79° 08′ E on a small strip of land lying east-west with Palk Bay to the north and the Gulf of Mannar to the south.

Material and Methods

Material for the present study was derived from weekly plankton collections from Palk Bay and the Gulf of Mannar during the period January 1955 to December 1958. A total of 332 samples, 182 from the Gulf of Mannar and 150 from Palk Bay have been examined. The collections were made by 15 minute surface hauls by a 50 cm. diameter net of organdy cloth (*ca* 36 strands per cm.) towed from a motor launch between 06·00 and 07·00 hours. The samples were made up to 250 c.c. and preserved in 5% formalin (40% formalin was poured into the sample till the whole sample reached a strength of about 5%). This method of preservation always gave satisfactory results. From each of the samples a subsample of 5 c.c. was pipetted out with the help of a Stempel's pipette and the chaetognaths from these fractioned samples were picked, identified and recorded. In the majority of the cases staining of the specimens was not necessary for identification. In difficult cases staining was done as suggested by George (1952) to facilitate correct identification.

The data on temperature and salinity were obtained from the records maintained by the Central Marine Fisheries Research Institute, Mandapam Camp.

Hydrographical Conditions

Salinity values are available for the years 1955, 1956 and 1958. The salinity of the surface waters in both the Gulf of Mannar and Palk Bay shows a similar pattern of variation with steady increase from low values in January to June-July. They remain more or less steady till about September-October with the highest values in September. Thereafter a sharp decline is noticed and by December very low values are again obtained. Jayaraman (1954)

observed that, " High values for salinity are observed in the period, May to October, while low values are to be found between November and April. It may be noted that the earlier months of these two periods coincide with the two monsoons, south-west and north-east. Thus it is seen that salinity is high during the months of the south-west monsoon and low during those of the north-east monsoon". The present data are also in conformity with the above remark.

Temperature data are available for all the four years 1955 to 1958 from the Gulf of Mannar. But unfortunately they are not available from Palk Bay. The general characteristics of the surface temperatures of sea-water at Mandapam were discussed by Prasad (1957) based on five years' data from the Gulf of Mannar. The present values also exhibit a similar trend.

Observations

List of Species Recorded

The waters around Mandapam are rich in Chaetognatha. The following species have been recognised from the plankton of the Gulf of Mannar and Palk Bay:—

Genus *Sagitta* Quoy and Gaimard, 1827 :

1. *Sagitta enflata* Grassi, 1881;
2. *S. neglecta* Aida, 1897;
3. *S. bedoti* Beraneck, 1895;
4. *S. robusta* Doncaster, 1903;
5. *S. tenuis* Conant, 1896;
6. *S. pulchra* Doncaster, 1903;
7. *S. hispida* Conant, 1895.

Genus *Krohnitta* Ritter-Zahony, 1911:

8. *Krohnitta pacifica* Aida, 1897;
9. *K. subtilis* Grassi, 1883.

Genus *Spadella* Langerhans, 1880 :

10. *Spadella cephaloptera* Busch, 1851.

Of the three genera occurring in the Mandapam waters *Sagitta* is by far the most common. *Krohnitta* occurs in comparatively fewer numbers. *Spadella* which is known to be a benthic form is extremely rare and only four

specimens were observed in the samples from Palk Bay during the whole period of study. Varadarajan and Chacko (1943) recorded a total of six species, *viz.*, *S. enflata*, *S. tenuis*, *S. robusta*, *S. neglecta*, *K. pacifica* and *Sp. cephaloptera* from Krusadai. Subsequently, George (1952) identified *S. bedoti*, *S. pulchra* and *Pterosagitta draco* from the Gulf of Mannar. The last-named species, however, was not observed during the present study. The record of *K. subtilis* is the first for this area.

Small numbers of very young ones were encountered in the samples and their identification was difficult due to their smallness of size. These, together with certain doubtful specimens, formed only a very negligible percentage of the total number of specimens examined and as such are not taken into consideration.

Chaetognaths occur in the plankton of the Gulf of Mannar and Palk Bay all through the year but show qualitative and quantitative fluctuations during the different months of the year (*see* Figs. 1 and 2). In Palk Bay the peak occurrence is during July-September. Two minor peaks are observed during February-April and October to December. In the Gulf of Mannar, however, they are at their maximum during the period January-March. Their occurrence does not show any regular sequence during the second half of the year as observed by Prasad (1954). But generally a minor peak is observed during November-December. In 1958 this peak was more prominent than the peak in January. Besides, one or two peaks of lesser magnitude may be observed in the intervening months.

Though the species composing the chaetognath fauna of the two areas under study are the same, excepting *Spadella cephaloptera*, which was found only in Palk Bay, the inter- and intra-specific fluctuations are different and the individual species have their own maxima and minima during the different seasons of the year, at the two stations studied. Quantitatively the Gulf of Mannar is richer in chaetognaths than Palk Bay. In the former area January to March, August and November to December are rich months while, April, September and October are the poorest months. In the latter area the second half of the year, in general, is comparatively richer than the first. July-September are the richest months. During the rest of the year they are few in number, May being the poorest month.

A comparison of the seasonal fluctuation of the individual species in the two areas studied brings out some interesting differences in the behaviour of the species concerned. Of the nine planktonic species only six, namely *Sagitta enflata*, *S. bedoti*, *S. neglecta*, *S. robusta*, *S. tenuis* and *Krohnitta pacifica* occurred in sufficiently good numbers over the period of study and their

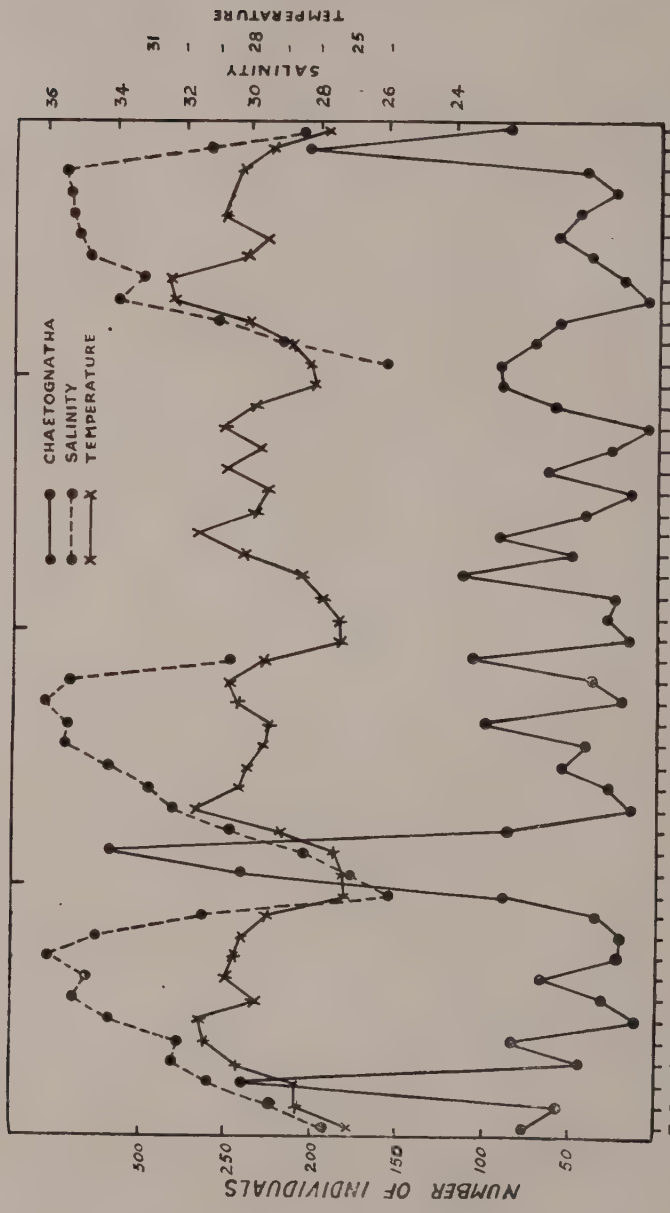

FIG. 1. The distribution of total Chaetognatha in the Gulf of Mannar.

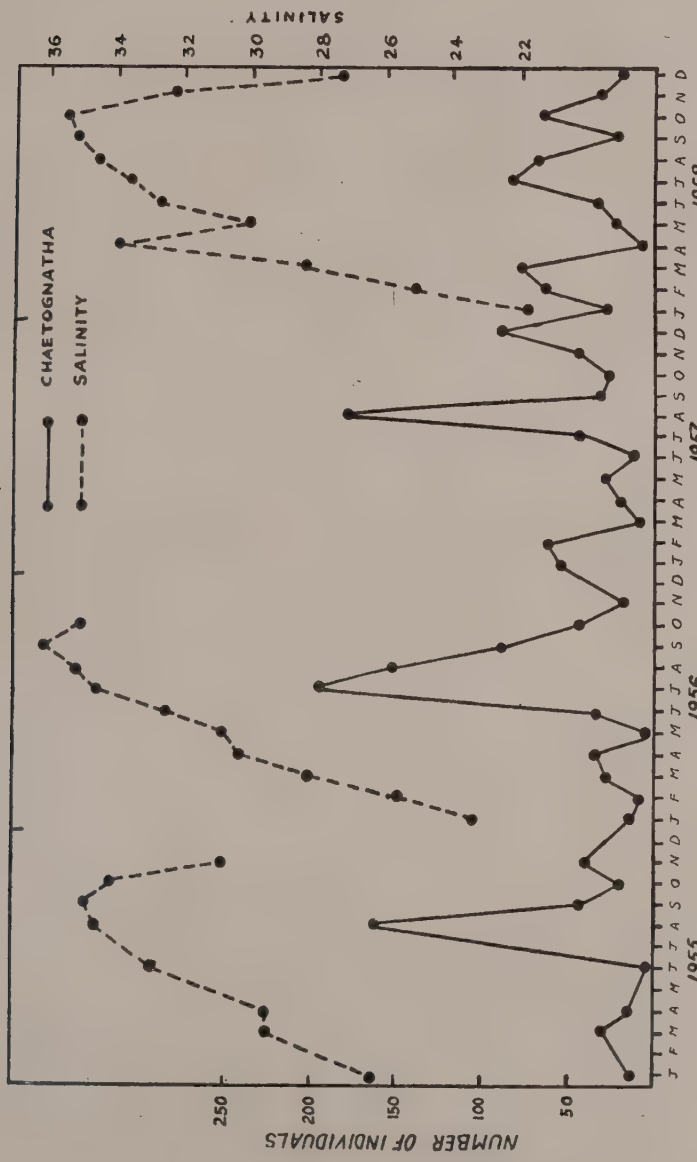

FIG. 2. The distribution of total Chaetognatha in Palk Bay.

seasonal fluctuations are compared. Figures 1 and 2 represent the seasonal abundance of Chaetognatha in Palk Bay and the Gulf of Mannar for a period of four years (1955–58). Figures 2–6 give the seasonal fluctuation of the six species from both the areas during the period of study. The numbers on the ordinate indicate the total counts for an aliquot of 5 c.c. from the standardised samples. The salinity and temperature for the corresponding period have also been plotted against the data in the first four figures. The remaining three species, *S. pulchra*, *S. hispida* and *K. subtilis* occurred only very rarely and as such they are not considered for a comparative study.

Sagitta enflata (Figs. 3 and 4).—This is a cosmopolitan species which can be easily recognised. It is the most common and numerically the most abundant species in the Gulf of Mannar occurring all through the year in varying numbers. There are no well-defined maxima and minima though it may be said in general that they are more abundant during the November-March period which falls in the low salinity, low temperature period of the year. However, two peaks of considerable magnitude are always observed one during February-March and the other during November-December. One or two more peaks of lesser intensity are observed during the remaining months. In 1957, however, there was a distinct decrease in numbers during November-December. In general, during the second half of that year, the population was comparatively at a lower level. The numerical strength of the *enflata* population in the Gulf of Mannar may be judged by the fact that as many as 656 individuals were present in a subsample of 5 c.c. during November 1958.

In Palk Bay, *S. enflata*, numerically, is only second in importance, *S. neglecta* being the most abundant species. Large numbers of this species are found invariably in the latter part of the year during August-September and sometimes also in November-December. A distinct minor peak was observed during February 1958 only, during which year it was relatively more abundant than in the preceding three years. It is interesting to note that the major peak of this species in Palk Bay falls in the high salinity period unlike in the Gulf of Mannar where the maximum numbers occur in the low salinity, low temperature months.

Sagitta neglecta (Figs. 3 and 4).—In the Gulf of Mannar it occurs during a greater part of the year being numerically, fourth in importance. The occurrence of this species here appears to be a little erratic. However, there is an apparent tendency for this species to occur in the plankton in good numbers during January-March when the salinity and temperature are low. In 1957 considerable numbers were obtained during April-May, August

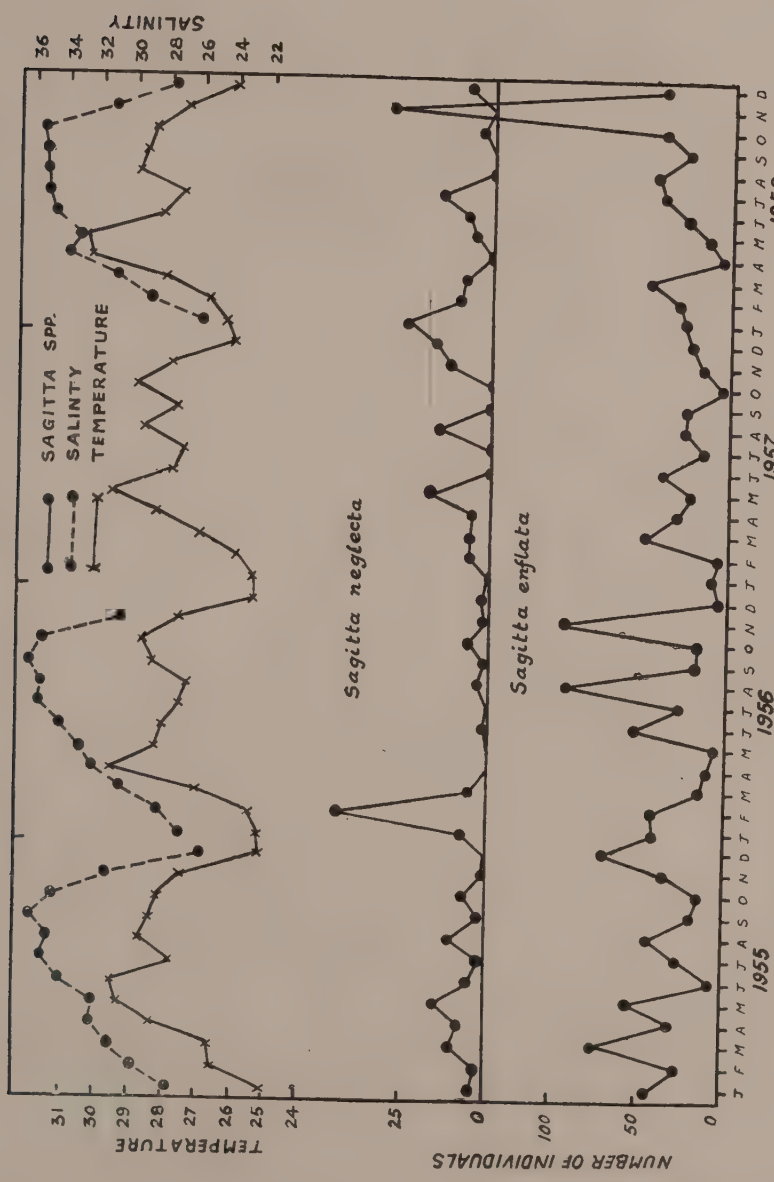
SAGITTA SPP.
SALINTY
TEMPERATURE
SALINITY
TEMPERATURE
Sagitta neglecta
Sagitta enflata
NUMBER OF INDIVIDUALS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1955
1956
1957
1958

FIG. 3. The distribution and fluctuation of *Sagitta enflata* and *S. neglecta* in the Gulf of Mannar.

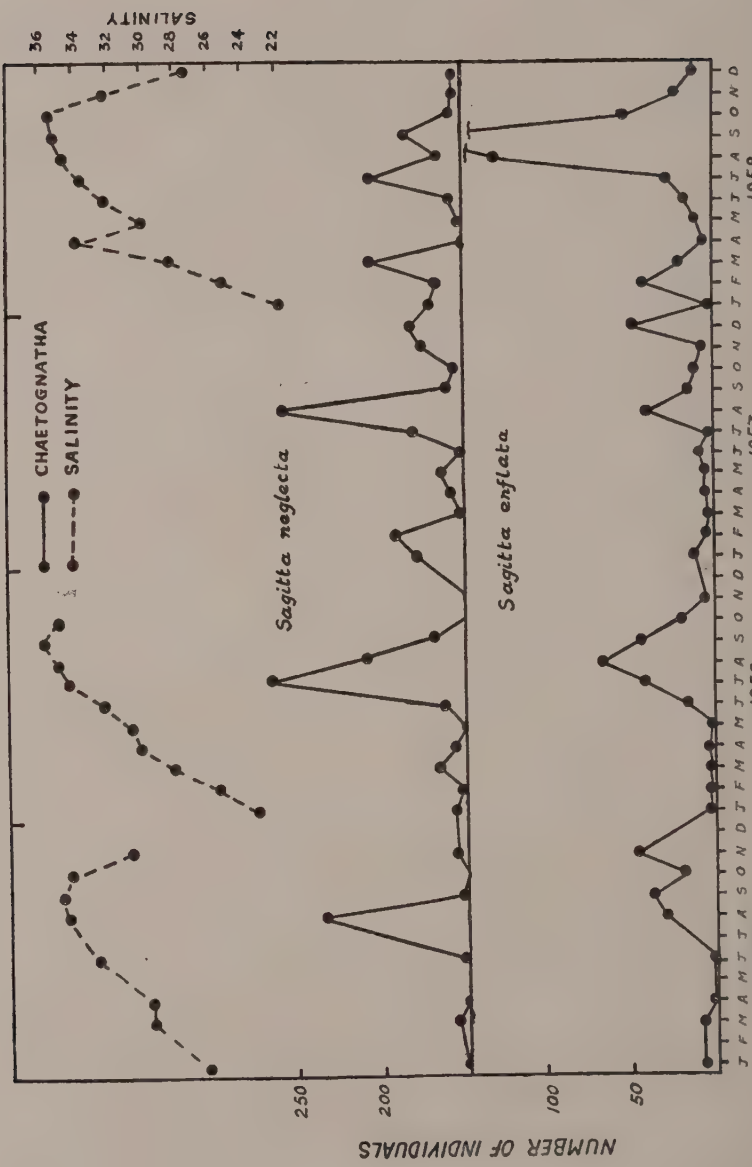

FIG. 4. The distribution and fluctuation of *Sagitta enflata* and *S. neglecta* in Palk Bay.

and November-December. As already stated, *S. neglecta* is the most abundant species in Palk Bay. It occurs in the plankton all through the year with a clearly demarcated maximum in the July-September period. At other times they are observed in lesser quantities showing irregular rises and falls. In 1958 there was an unusual increase of *S. neglecta* during March and April. It is of interest here, to note that the peak of occurrence of this species always coincides with the high salinity months just as in the case of *S. enflata* in this area.

Sagitta bedoti (Figs. 5 and 6).—This species is common in the Gulf of Mannar particularly during January-March when the salinity and temperature are low. During the rest of the months there is a decimation in their numbers (with occasional pulses) and sometimes it may even be entirely absent. In 1956 the *bedoti* population was at a very high level. It should be noted in this instance that the juveniles were predominant in the samples. In 1955 also they were fairly abundant though not as much as in 1956. In Palk Bay this species occurs sporadically in much smaller numbers and may even be absent for fairly long periods during the year. In 1957, for instance, they were totally unrepresented in the plankton from the middle of March to the middle of October.

Sagitta robusta (Figs. 5 and 6).—This is one of the important species occurring in the waters of Mandapam and is observed in fairly good numbers in the Gulf of Mannar for a considerable part of the year. It is common during the months when salinity and temperature are low, *i.e.*, January-March and thereafter a general decline is observed till July-August when it appears in small numbers for a short period. In 1957, however, its pattern of occurrence was different from that in the other three years and comparatively fewer numbers were observed during January and February. It was absent for a short period in March only to appear again from the latter half of March and April followed by another decline. During May and June it reached the maximum for the year. Fairly good numbers were encountered during October-December. In Palk Bay *S. robusta* is less common having a somewhat irregular pattern of distribution. It was fairly common only in 1956 showing two peaks one in April and the other during October-November. In 1955, 1957 and 1958 it was absent in the plankton for more than half of the year.

Sagitta tenuis (Figs. 5 and 6).—This occurs both in the Gulf of Mannar and Palk Bay, being relatively more common in the former. In the Gulf of Mannar it shows a peak of occurrence between January and April (low salinity, low temperature period) except in 1957 in which year this species

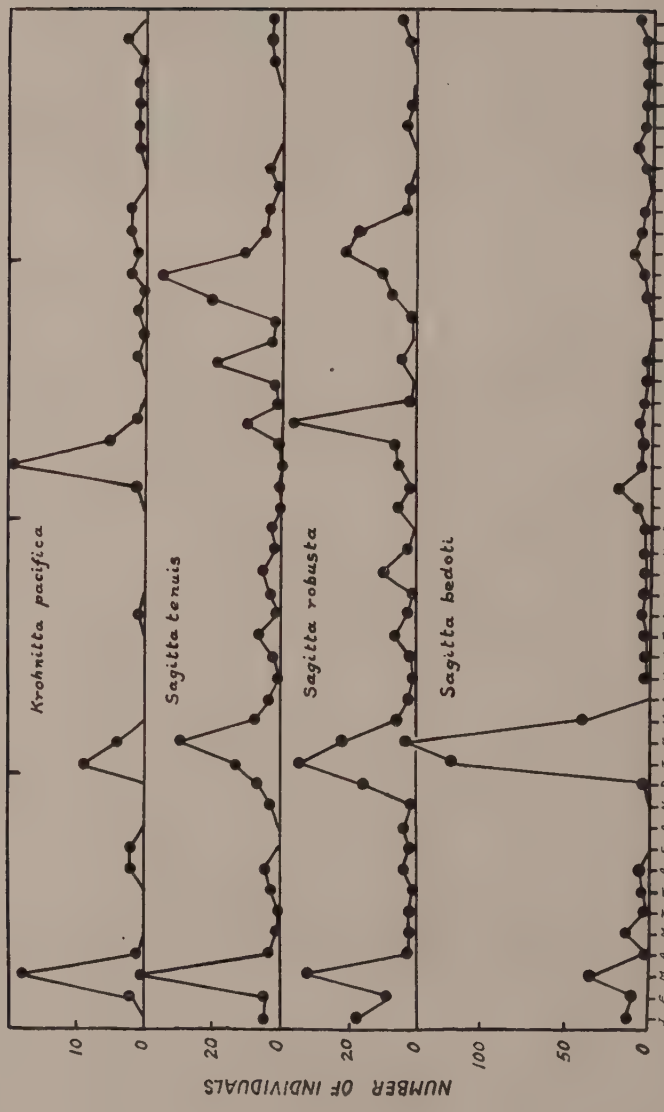

FIG. 5. Seasonal distribution of *Sagitta bedoti*, *S. robusta*, *S. tenuis* and *Krohnitta pacifica* in the Gulf of Mannar.

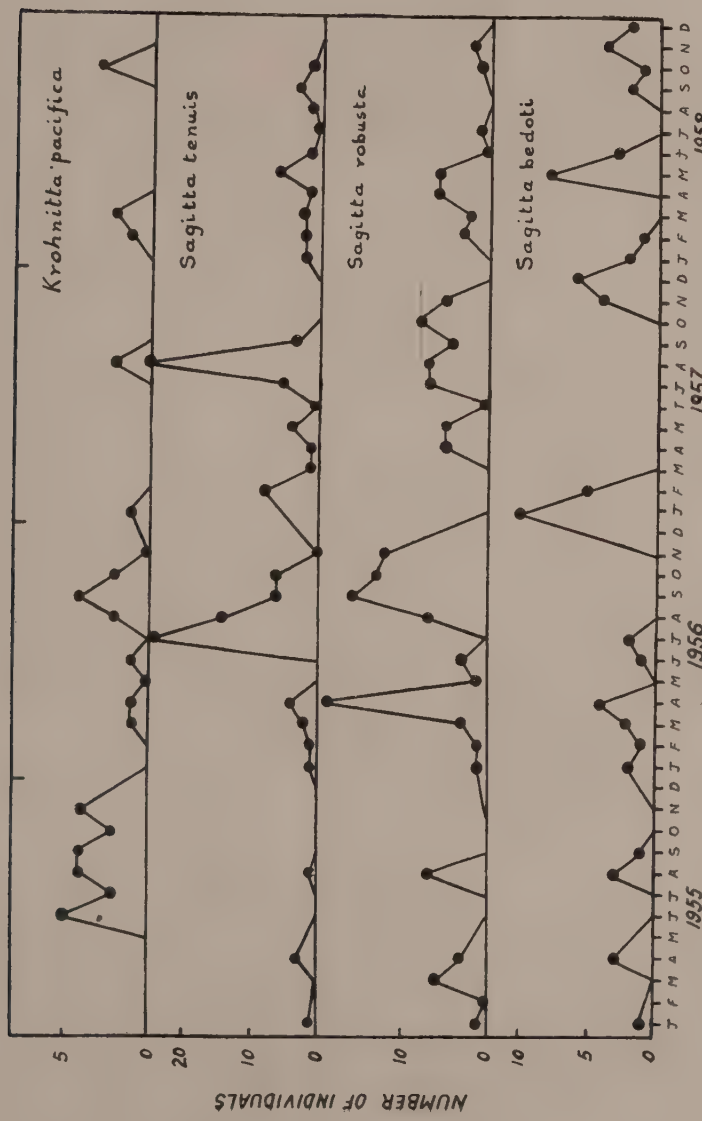
Krohnitta pacifica
Sagitta tenuis
Sagitta robusta
Sagitta bedoti
NUMBER OF INDIVIDUALS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1955
1956
1957
1958

FIG. 6. Seasonal distribution of *Sagitta bedoti*, *S. robusta*, *S. tenuis* and *Krohnitta pacifica* in Palk Bay.

was encountered in fairly large numbers in November-December, May and July-August. For the rest of the year it is either few, rare or absent. In Palk Bay it is not present in the plankton for a larger part of the year than in the Gulf of Mannar. In 1955 and 1958 it was poorly represented. In 1956 and 1957 however, the species occurred in very moderate numbers in July and August, being rare or absent during the rest of the months.

Krohnitta pacifica (Figs. 5 and 6).—Of the two species of *Krohnitta* occurring at Mandapam, *K. pacifica* is more common and is fairly frequently seen in the samples from the Gulf of Mannar during January-March. Just as in the case of the other five species of chaetognaths its peak also coincides with the general chaetognath maximum. Appreciable numbers of *K. pacifica* are never encountered in the samples from Palk Bay and its occurrence here is very irregular.

Discussion

From the foregoing account on the Chaetognatha of the Mandapam waters it is evident that they occur in the plankton of the Gulf of Mannar and Palk Bay throughout the year with certain qualitative and quantitative fluctuations during the different months and between different years. Earlier studies from the different parts of the country (Lele and Gae, 1936; John, 1937; Subramaniyam, 1937; Varadarajan and Chacko, 1943; George, 1952; and Rao, 1958 *a* and *b*) reveal that the chaetognaths are present in the Indian coastal waters all round the year. The chaetognath maxima and minima are observed in different months of the year in the different centres. At Bombay *Sagitta* is abundant during January, April-September and December. Menon (1945) observed huge swarms occurring irregularly during May to September with the onset of the South-West Monsoon. Off Calicut, George (1952) recorded a major peak during October-November. According to John (1937) April to August is the peak period at Madras. At Lawson's Bay, off Visakhapatnam, Rao (1958 *a*) observed the maximum right in the middle of the South-West Monsoon during July-August. In the Gulf of Mannar maximum occurrence of Chaetognatha is during November-March, whereas in Palk Bay the peak occurs during July-September. Whether the fluctuations in Chaetognatha as a group are directly related to the changes in salinity has not been adequately explained by the earlier workers. The investigations at Mandapam bring out certain interesting features. Prasad (1956) referred to the significant time difference in the occurrence of maxima in the Gulf of Mannar and Palk Bay. In the former area they are at their maximum when the temperature

and salinity are low, whereas in Palk Bay the peak falls in the high salinity months. Further, the fluctuations of total chaetognaths from month to month are greater in the Gulf of Mannar than in Palk Bay just as in the case of total plankton volume (Prasad, *loc. cit.*). A detailed investigation reveals that while the maximum during January-March (low salinity — low temperature) in the Gulf of Mannar is a result of the simultaneous occurrence of many species (*Sagitta enflata*, *S. robusta*, *S. bedoti*, *S. neglecta* and *S. tenuis*) in sufficient numbers, the peak in Palk Bay is due to the large–scale occurrence of *S. neglecta* and *S. enflata*. Off Calicut the major peak during October-November (period of high salinity) is due to the occurrence of *S. enflata* and *S. neglecta* in large numbers, just as in Palk Bay. Off Trivandrum *S. enflata* and *S. tenuis* are conspicuous from May to September which is the peak period off that coast. At Madras all the seven species recorded reach their maximum during the summer months thus contributing to a total chaetognath maximum. The salinity during these months at Madras is high (Thirupad and Reddy, 1959). Off Visakhapatnam large numbers of *S. enflata* and *S. bedoti* contribute to the major peak during July-August when the salinity and temperature are fairly high. At Bombay *S. bombayensis*, *S. enflata* and *S. bedoti* are the species constituting the maximum.

John (1937) is of the opinion that the period of maximum of *Sagitta* species depends on the nature of the local rainfall. But observations made from Palk Bay and the Gulf of Mannar, where conditions of rainfall are similar, reveal that rainfall (which directly influence salinity) is not the major factor affecting the occurrence of the maxima and minima. Menon (1945) observed " .... swarms of *Sagitta* have been recorded during the monsoon months when the salinity of the coastal waters is naturally lower than that during the rest of the year. It therefore seems probable that the intensity of *Sagitta* during the rainy season is not much to be attributed to the changes of salinity as to the other factors....." It may here be pointed out that at Mandapam the peak period of Chaetognatha in both the bodies of water coincide with the periods when the respective waters are calm (*see* Prasad, 1958). It is quite probable that this physical factor is of consequence in controlling the abundance of these forms.

A comparison of the fluctuations of Chaetognatha in Palk Bay and the Gulf of Mannar with those of the copepod populations reveals a close relationship. Prasad (1956) observed that in the Gulf of Mannar the copepods exhibit a dicyclic pattern with a major peak during January-March and a minor peak during September-October and that in Palk Bay they show a

steady increase during the early part of the year reaching a maximum during September-October. Kartha (1959) confirmed these observations. Thus it may be seen that the chaetognath cycles in both the areas closely follow those of the copepods. Prasad and Kartha (1959) studied the breeding of copepods and found that it is to a very large extent dependent upon the diatom cycle. According to them the maximum breeding of copepods takes place during September and March in the Gulf of Mannar and May-September in Palk Bay. Chaetognath maxima at both the places fall during the period of maximum breeding of copepods. Chaetognaths are known to feed on copepods, larval fish and probably diatoms. Bigelow (1926) said that reduction of copepod numbers may be more due to the feeding by chaetognaths than by fish. Nauplii, copepodites and adult copepods were frequently observed in the guts of *Sagitta* spp. during the present investigations. Diatoms, fish larvae, pteropods and *Sagitta* spp. were the other items encountered. From the above it may be inferred that the seasonal abundance of Chaetognatha is influenced by the copepod cycle particularly in view of the fact that the latter forms an important item of food of the former.

A closer examination of the fluctuations of the individual species at different places of the Indian coast enables certain generalizations to be made. Off Bombay, Calicut, Visakhapatnam, Madras and in Palk Bay, *Sagitta enflata* occurs in large numbers only when the salinity and temperature are fairly high and steady. But off Trivandrum and in the Gulf of Mannar it is seen not only to tolerate lower salinities but occur in huge swarms during July-September and November-March respectively. Regarding the sporadic occurrence of *S. enflata* in large numbers off Calicut during the monsoon months George (*loc. cit.*) remarks that it may " be correlated with the abnormal salinity, pH, phosphates and silicate values recorded during the period, indicating the possibility of a sudden influx of oceanic water affecting inshore areas". The difference in the behaviour of *S. enflata* in the Gulf of Mannar and Palk Bay, despite the similarity in the salinity-temperature features, suggests the possibility that the populations of *S. enflata* in these two areas are different. It is also probable that this species is tolerant of a wide range of temperature and salinity. However, further investigations have to be carried out before these possibilities are confirmed. *S. neglecta* occurs in the plankton in large numbers off Calicut, Madras and in Palk Bay when the salinity is high. In the Gulf of Mannar appreciable numbers of *S. neglecta* are not encountered. Off Visakhapatnam this species occurs in good numbers only in the offshore region. Rao (1958 *b*) suggested the possibility of considering this species as an indicator of offshore waters off the Visakhapatnam coast. Palk Bay being more or less an enclosed body

of water is not subjected to any great influence from the offshore waters of the Bay of Bengal. Off Madras this species reaches its peak during May-June. In Palk Bay this species has its peak during July-September. It is quite probable that *S. neglecta* is brought down from the north by coastal currents flowing south. Until a better knowledge of the coastal currents affecting these waters is obtained it would be difficult to satisfactorily explain the abundance of *S. neglecta* in Palk Bay during July-September or to substantiate the above probability.

In the Gulf of Mannar and off Calicut, *Sagitta bedoti* and *S. robusta* occur in the low salinity months in sufficiently good numbers. However, at Lawson's Bay *S. bedoti* is abundant only when the salinity is quite high. This difference in the behaviour of *S. bedoti* cannot be adequately explained at present in the absence of details regarding its biology. Rao (1958 *a*) suggested that this species may be considered as an indicator of near-shore waters of Visakhapatnam. In the waters off Mandapam *S. bedoti* does not appear to be of any indicator value. But this species seems to thrive better in low salinity and low temperature water at Mandapam. Off Visakhapatnam also *S. robusta* is found to occur in fair numbers during the low salinity months just as in the Gulf of Mannar. Hence it would appear that *S. robusta* prefers lower temperature and salinity. Similarly in the case of *S. tenuis* also the observations from Calicut, Trivandrum and Gulf of Mannar indicate that lower salinity is favourable for the success of this species. Pierce (1958) considered *S. tenuis* and *S. hispida* as characteristic of inshore waters off North Carolina. Detailed investigations into the feeding and reproductive habits of the different species may be of use for a better understanding of their seasonal fluctuations.

Rao (1958 *b*) considered *Sagitta serratodentata* var. *pacifica* as an indicator of oceanic waters off the Visakhapatnam coast. The absence of this form as well as other typical oceanic species like *S. planktonis* is interesting in view of the fact that the Gulf of Mannar is an open body of water known to have oceanic influence. The latter-named species was recorded at Madras by John (1937).

Varadarajan and Chacko (1943) observed that the major peak for Chaetognatha around Krusadai occurs during September-December and they suggested that chaetognaths are brought down by the southward flowing current from Palk Bay through the Pamban channel. The peak at Krusadai thus follows the peak in Palk Bay which occurs during July-September. *Sagitta enflata*, *S. tenuis*, *S. robusta* and *S. neglecta* are the species responsible for the peak at Krusadai. In Palk Bay *S. enflata* and *S. neglecta* are the

two species constituting the peak. Thus the two species responsible for the peak in Palk Bay are well represented in the Krusadai samples and as such it is probable that the presumption of Varadarajan and Chacko is correct.

For a fuller and better understanding of the part played by the chaetognaths in the Indian coastal waters as indicators, a clear picture of the oceanic currents, particularly those which are of significance in the coastal areas, is essential. Till now most of the studies in the Indian waters have been based on plankton collections made not far from the shore and as such no more than broad generalizations on the relationship between the chaetognath species and the prevailing hydrological conditions are possible. Examination of samples from wide areas extending far out into the sea will be of considerable value in assessing their importance as indicator species in the Indian coastal waters.

Summary

Observations on the Chaetognatha of the Gulf of Mannar and Palk Bay were made. Weekly surface plankton samples from January 1955 to December 1958 formed the material for this study.

Ten species, *Sagitta enflata*, *S. neglecta*, *S. robusta*, *S. bedoti*, *S. tenuis*, *S. hispida*, *S. pulchra*, *Krohnitta pacifica*, *K. subtilis* and *Spadella cephaloptera* are recognised from the samples. The first nine species are common to both the Gulf of Mannar and Palk Bay but the last-mentioned species is recorded only from Palk Bay. The record of *K. subtilis* is new for this area. Of the two areas studied Gulf of Mannar is quantitatively richer in Chaetognatha, November to March being the period of abundance. In Palk Bay Chaetognatha are invariably more abundant in the second half of the year, the peak period being July-September.

The maximum during January–March in the Gulf of Mannar is constituted by *Sagitta enflata*, *S. bedoti*, *S. neglecta*, *S. robusta* and *S. tenuis*. In Palk Bay the peak is mainly a result of the large-scale occurrence of *S. neglecta* and *S. enflata*. A study of the seasonal fluctuations of the different species in relation to the hydrological conditions suggests that *S. robusta*, *S. bedoti* and *S. tenuis* prefer lower salinities.

The existence of a close relationship between the chaetognatha and copepod cycles in both the Gulf of Mannar and Palk Bay is pointed out. The probability of *Sagitta neglecta* being brought down from the north into Palk Bay by coastal currents is indicated. The possibility of the existence

of two different populations of *S. enflata* in the Gulf of Mannar and Palk Bay is also suggested.

Acknowledgements

The author expresses his grateful thanks to Dr. S. Jones, for his interest in the investigations and to Dr. R. Raghu Prasad for his guidance from time to time and for critically going through the manuscript and suggesting improvements. The author also acknowledges the help rendered by Shri A. C. Sekhar in the preparation of the graphs.

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OBSERVATIONS ON THE BIOLOGY AND FISHERY OF *METAPENAEUS BREVICORNIS* (M. EDW.) IN THE HOOGHLY ESTUARINE SYSTEM

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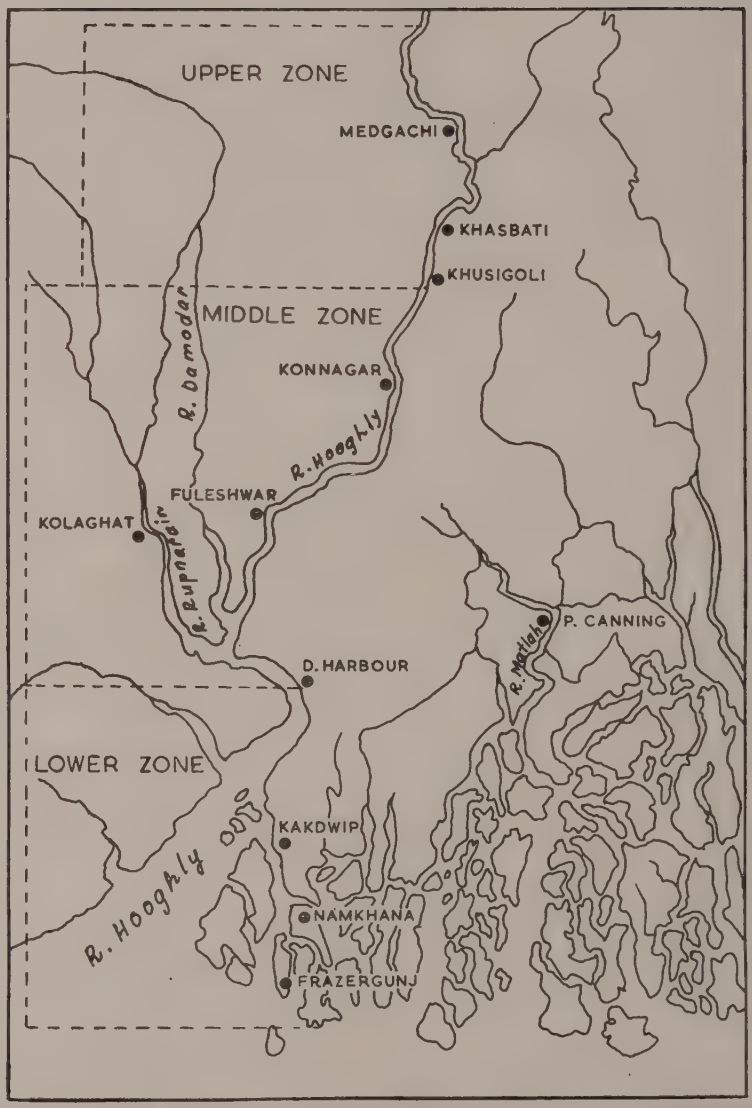
Several species of Penaeid prawns ascend the Hooghly estuarine system, as juveniles, where they contribute considerably to the commercial catches. Such of those juveniles that enter 'bheris' and paddy fields constitute the varieties that are cultured widely in deltaic Bengal. Amongst these various species *Metapenaeus brevicornis* (M. Edw.) locally known as 'Dhanbone chingri' is the "commonest Penaeid of Bengal occurring very plentifully in the delta of Ganges" (Chopra, 1939 and 1943; Panikkar and Menon, 1955). Alcock (1906) has recorded the distribution of the species as in India, Mauritius and Borneo. He has also recorded that the species rarely attains a length of 5″. In the present studies also the largest female recorded is 120 mm. (4·75″). Considering the commercial importance of this species a knowledge of various aspects of its biology has been considered essential both for a proper management of its fishery in the estuaries as well as for recommendation of its large-scale culture, and hence this study.

Several workers from other countries have investigated into various aspects of the biology of prawns, both Carideans and Penaeids. (Gurney, 1923; Hoglund, 1943; Lloyd and Yonge, 1947; Forster, 1951 *a* and *b* and 1959; Kubo, 1951 and 1955; Pike, 1952; Lindner and Anderson, 1956; Dall, 1958 and Cole, 1958). However, contributions to the knowledge of the biology of prawns from Indian waters are few. Among others Menon (1951, 1953, 1955 and 1957), and George (1959) have studied certain aspects of the life-history and biology of several species of Penaeids, whereas Kunju (1955) worked on the biology of *Leander styliferus*.

Material and Methods

Material for this study stems from the commercial catches of the Hooghly estuarine system, collected fortnightly from thirteen randomly selected sampling centres (3 along Roopnarain, one on Matlah and nine on Hooghly) (Text-Fig. 1). The entire stretch of the estuary can be divided, based on the



TEXT-FIG. 1. Map of Hooghly estuarine system, showing the sampling centres and zones.

pattern of fluctuations in salinity, into three zones: an upper zone corresponding to freshwater zone, where salinity is in traces throughout the year; a middle zone corresponding to the gradient zone, where salinity fluctuates

from traces to 11·42 parts per thousand, and a lower zone corresponding to the tidal zone where salinity fluctuations are in the range of 6·32–29·89 parts per thousand (unpublished records of the Institute). The samples are drawn mostly from Bagnets (Bhinjals) and barrier nets (Kalpatajals).

The total length of the individuals was measured from the tip of rostrum to tip of telson. Weights were taken to the nearest gram, in a trip type of double-pan balance. Lengths at ages were calculated separately for males and females. Separation of sexes by external examination was possible in specimens measuring more than 20 mm., since the rudiment of the petasma on the protopodite of the first pleopod of male is not generally clearly visible in specimens smaller than that size. The individuals examined for this study ranged between 15 and 115 mm. Smaller specimens were not available even in the $\frac{1}{2}$ meter townet (made of muslin cloth) catches made in the estuary. For age studies the different size groups in the polymodal length-frequency distributions of males and females for 1959, 1960 were separated by the use of probability paper (Harding, 1949; Cassie, 1954 and Pantulu, 1962). Probability plot analysis was found to be a useful tool in the separation of different age-groups and in the determination of specific and seasonal growth of the species. However, there are certain limitations to this method, and as observed by Pantulu (*op. cit.*) " one of the serious limitations of this method was found to be the diagnosis of points of inflexion in the cumulative percentage curve ...." " However, by trial and error a fairly accurate choice of inflexion points was found possible in such cases."

Age and Growth

Estimation of age has been done only in respect of a few species of Indian prawns (Menon, 1951, 1953 and 1955; George, *op. cit.* and Kunju, *op. cit.*) by the modes of length-frequency distributions. This method, which is commonly known as ' Peterson's method ', has been demonstrated to be inadequate particularly in respect of species which have a prolonged spawning season. Further, non-representation of certain year classes in the commercial catches and increasing overlap of distribution of older size groups is likely to yield erroneous results. Hence in this study, as mentioned earlier, the probability plot method (Harding, 1949; Cassie, 1954) of separating the polymodal length-frequency distribution has been used to find out the modal lengths of different year classes. Further, in the absence of alternative methods of estimation of age such as the use of periodic markings on hard parts, as in fishes, testing validity of the conclusions based on length-frequency analysis becomes difficult. Hence in this study estimates

of " length at age " as made independently by seasonal growth studies and progression of modal lengths in the length-frequency distribution during different months of the year have been used to verify the accuracy of the conclusions arrived at.

Table I shows the modal lengths and standard deviations of the component modal values of the polymodal length-frequency distributions during the years 1959 and 1960 separately of males and females. Normal curves fitted to the length-frequency distributions based on the probability plot analysis are illustrated in Text-Fig. 2. It is evident from these that both males and females are represented in the commercial catches by five approximately normally distributed size groups. The successive modes separated along the length axis have not been assigned to different age-groups in this case, as is usually done. The earliest mode has been assigned to the zero-group, since experiments on mesh selectivity of bagnets, from which these samples have been drawn, have indicated that the mean selection size of the species by bagnets is 22·711 mm. (Rajyalakshmi, unpublished). This observation lends support to the conclusion that the earliest mode does not represent the modal size of I year group. Of the subsequent modes two consecutive modes have been considered to represent one-year class because of the reasons given below.

1. The occurrence of females in advanced stages of maturity in the months January and February, and the availability of impregnated, soft-shelled females in the months of July-August coupled with the occurrence of young prawns having modal sizes of 23 mm. in July and 23–26 mm. in October-November probably indicates that the species has two spawning seasons, one in the early summer, *viz.*, March-April and the other in the monsoon months, *viz.*, July-August.

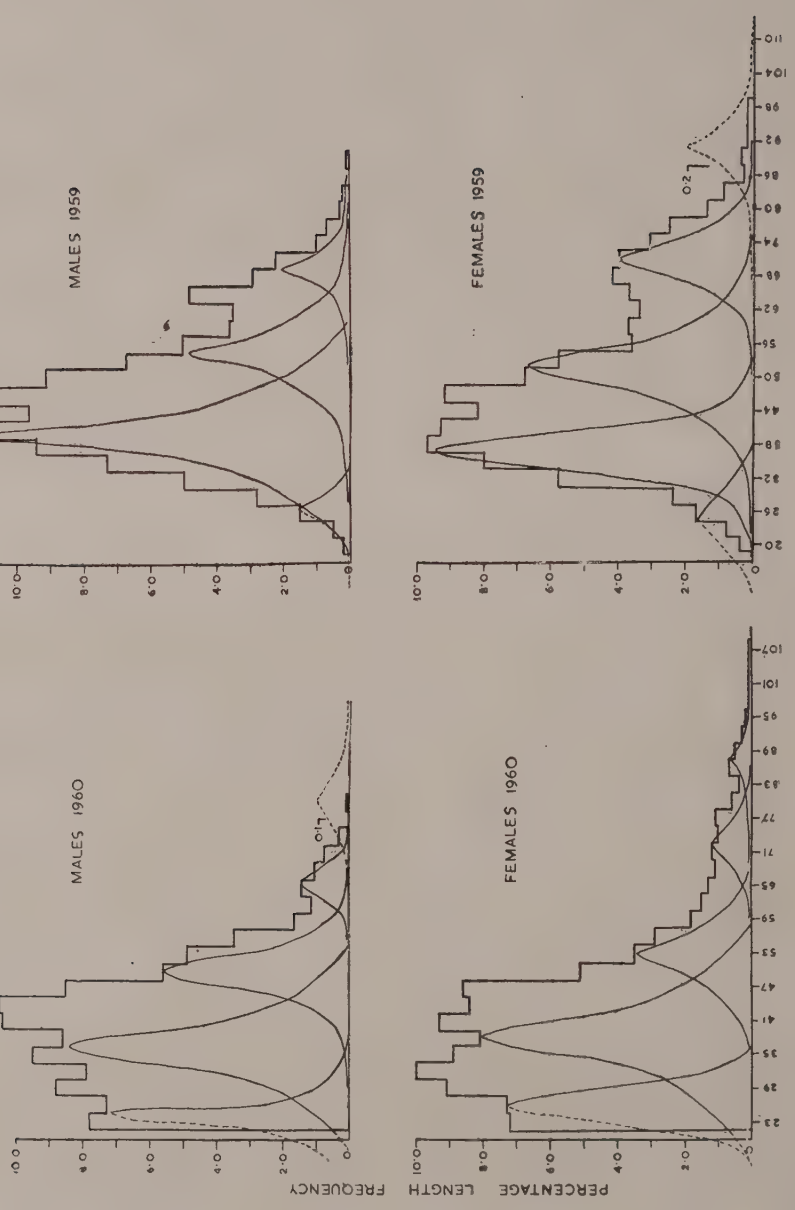
2. The availability of smallest modal sizes, *viz.*, 24·5–26·4 mm. in the months July and October-November tends to confirm the above observation, since the growth trends in zero-group individuals indicate that approximately 3–4 months time is required to attain a length of 24–26 mm.

The monthly progression of (Text-Figs. 3 and 4) modal sizes of the 0-year class indicates that, after the post-larval phase, the prawn grows approximately at a rate of 3 mm. for month. This, coupled with the occurrence of mature and soft-shelled females in the catches, indicate that the July and October-November earliest modal sizes are probably the results of previous March-April and July-August spawnings respectively.

TABLE I

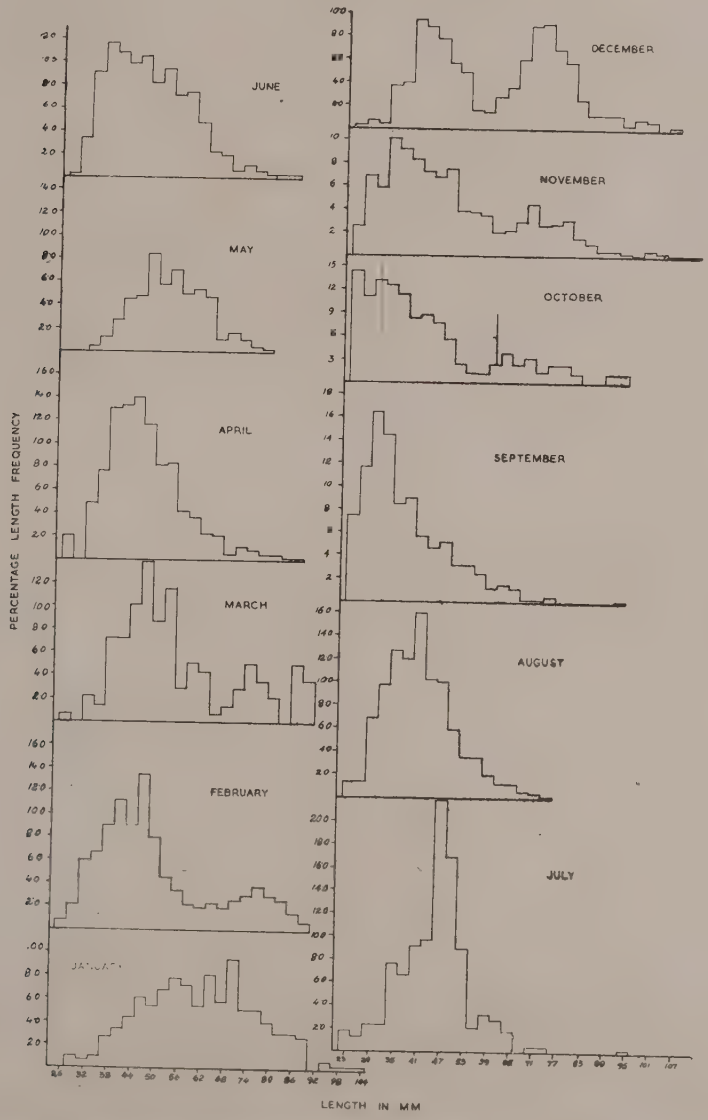
Modal lengths of different age-groups of M. brevicornis *as estimated by length-frequency analysis of samples from commercial catches of Hooghly, Matlah and Roopnarain estuaries*

Calendar year	Males					Females				
	0	I		II		0	I		II	
		Monsoon brood	Summer brood	Monsoon brood	Summer brood		Monsoon brood	Summer brood	Monsoon brood	Summer brood
1959	26·8 ±3·8	40·0 ±5·6	54·5 ±7·3	69·0 ±4·6	82·0 ±4·3	24·5 ±9·1	36·8 ±4·8	52·1 ±7·7	71·0 ±5·6	90·5 ±6·3
1960	24·8 ±3·4	37·2 ±4·6	49 6 ±5·8	66·0 ±3·5	79·0 ±4·97	26·0 ±2·9	38·0 ±5·5	52·8 ±5·3	72·5 ±4·4	87·5 ±5·7
Average ..	25·8	38·6	52·05	67·5	80·5	25·25	37·4	52·45	71·75	89·0

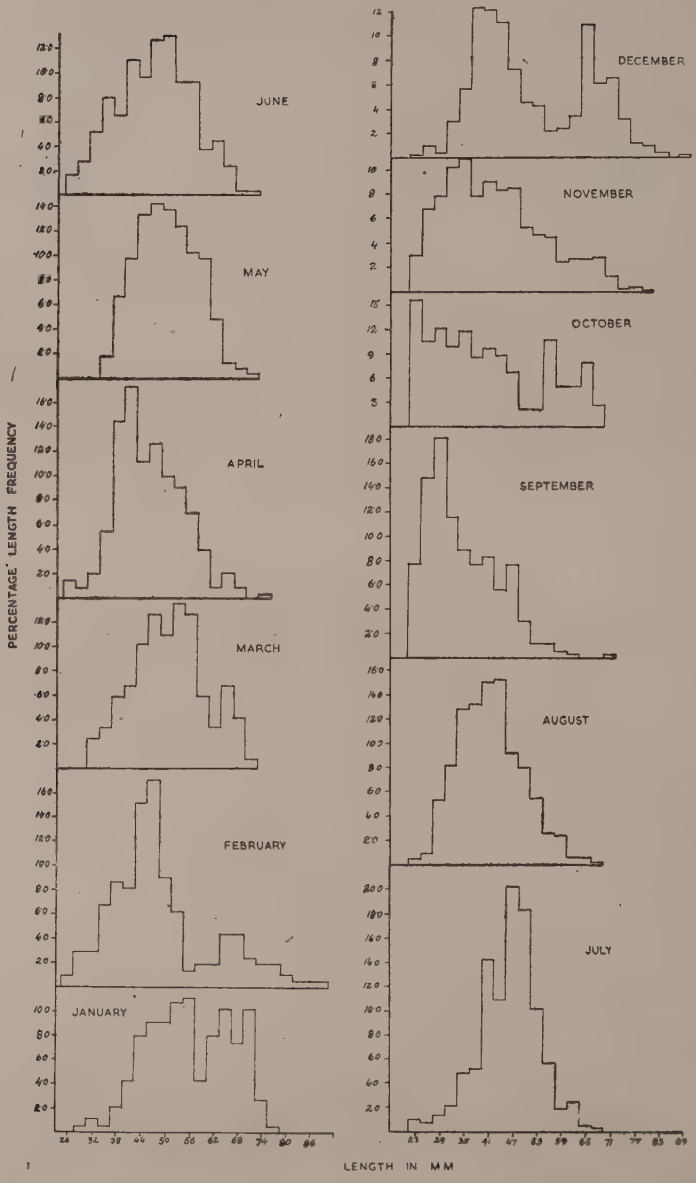


Text-Fig. 2. Histograms of length-frequency distribution of *M. brevicornis* (males and females) for 1959 and 1960. The polymodal frequency curves are dissected into their normal components by probability plot analysis.

In view of the facts mentioned two consecutive normal curves (Text-Fig. 2) have been taken to represent the size classes resulting from early and



TEXT-FIG. 3. Histograms of monthwise frequency distributions of males of *M. brevicornis*. Data are pooled for 1959 and 1960.



TEXT-FIG. 4. Histograms of monthwise length-frequency distributions of females of *M. brevicornis*. Data are pooled for 1959 and 1960.

late spawnings each year. The average lengths attained at different ages by females of these two broods are presented in Table II. The close agreement in the estimates of length at different ages made by tracing monthly progression of modal values in the length-frequency distributions (Text-Figs. 3 and 4) is taken to indicate the accuracy of these estimates.

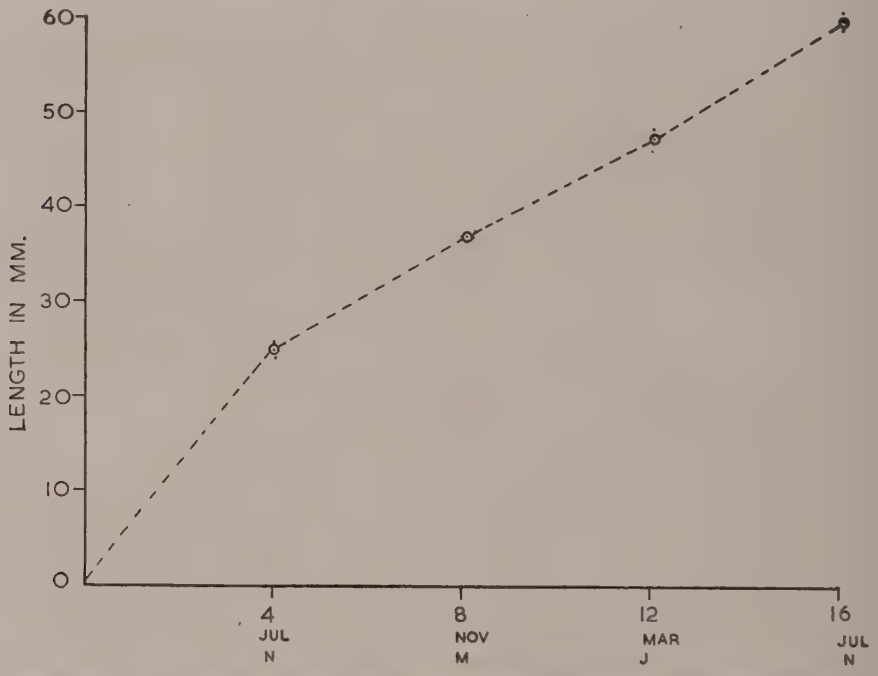
TABLE II

Seasonal pattern of growth (females)

Season	Month	Summer brood			Monsoon brood		
		Average modal size (mm.)	Specific growth (G)	Increment in length	Average modal size (mm.)	Specific growth (G)	Increment in length
	July	24·5	..	..	..	..	..
Monsoon		..	11·507	14·4	..	..	..
	November	38·9	..	..	26·5	..	..
Winter		..	2·966	4·9	..	6·920	8·4
	March	43·8	..	..	34·95	..	..
Summer		..	7·448	15·2	..	7·8535	12·9
	July	59·0	..	..	47·85	..	..
Monsoon		..	6·015	16·0	..	4·852	10·3
	November	75·05	..	..	58·1	..	..
Winter		..	..	..	..	3·187	7·9
	March	..	..	..	66·0	..	..
Summer							
	July	..	..	21·8	..	..	..
Monsoon							
	November	96·8	..	..	..	..	..

The rate of growth in females appears to be faster than that of males, indicating that sexual differences in growth rate exist in the species. Similar differences in allied species of prawns was noticed by Menon (1957). Text-Figures 3 and 4 show the apparent growth rate curves of male and female *M. brevicornis*. As is well known growth in size in crustaceans is essentially discontinuous since increases in the linear dimension take place abruptly at ecdysis and length, within the rigid exoskeleton, in the interval between moults remains constant (Teissier, 1960). In *M. brevicornis* the

growth of males and females is comparable during the first year of their life. One-year old males and females measure about 45·8 and 47·4 mm. respectively. Later the females appear to grow at a faster rate than males and at the age of 2 females and males attain lengths of 89·0 and 80·5 mm. respectively.

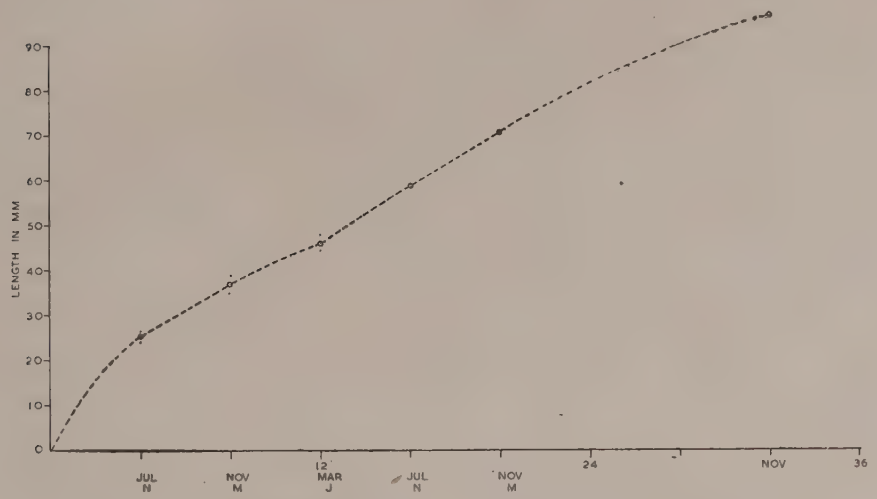


TEXT-FIG. 5. Approximate growth rate curve for females *M. brevicornis* (for details *see* text).

Text-Figures 5 and 6 represent the approximate growth rate of males and females respectively. The increments in length shown in the figures are derived from the seasonal growth studies. Increment in the length for both the broods separately in comparable durations of time, irrespective of season, have been plotted (dots) and their average values (circles) were connected by broken lines.

SEASONAL PATTERN OF GROWTH

To ascertain the seasonal pattern of growth the length-frequency distribution of samples obtained during the months March, July and November were analysed separately by the probability plot method. The three months



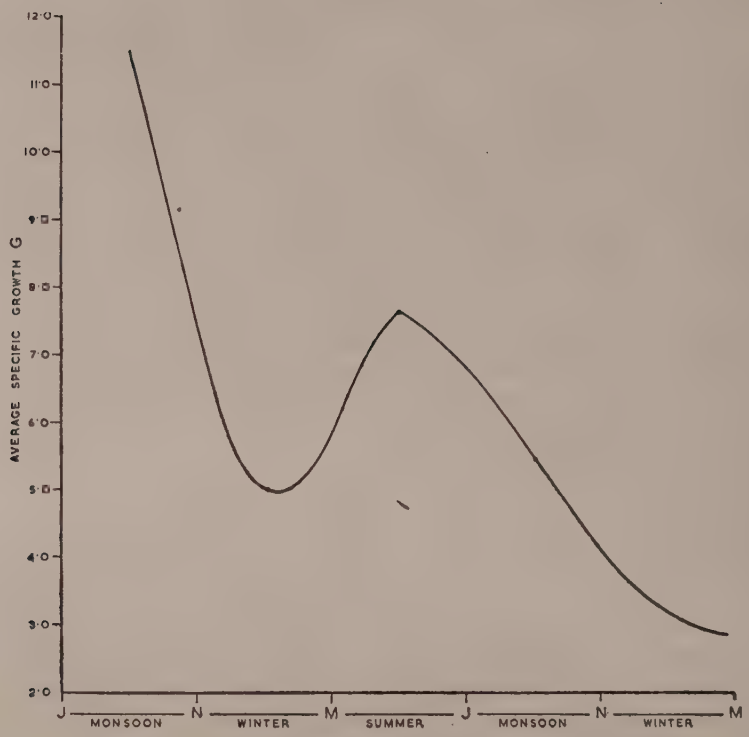
TEXT-FIG. 6. Approximate growth rate curve for males *M. brevicornis* (for details *see* text).

represent the commencements of the three principal seasons in this part of the country, *viz.*, summer, rainy season and winter. The increments in lengths attained between March and July, July and November and November and March are taken to indicate the growth during summer, rainy and winter seasons respectively. During the summer season, the temperature and salinity of the water in the estuary are high (ranging from 30·45–30·82° C. and salinities 4·3–29·1 parts per thousand). The rainy season is characterised by low salinity (traces to 9·47 parts per thousand) and fairly high temperature (30·08–30·8° C.) whereas, the winter by fairly high salinity (1·62–19·78 parts per thousand) and low temperature (21·85–23·7° C.). The growth of the sexes and broods was traced separately. Since growth is multiplicative and logarithmic expressions express it more adequately (Brown, 1957), specific growth rate ' G ' during different seasons was taken as an index for comparison:

$$G = 100\ g. = 100 \cdot \frac{\log_e l_T - \log_e l_t}{T - t}$$

(where l_T and l_t are lengths at times T and t, T being later than t).

Text-Figure 7 shows the seasonal fluctuations in specific growth rates for females. Estimates of ' G ' in respect of males have not been made due to paucity of data for different seasons for the I and II year groups. It appears



TEXT-FIG. 7. Specific growth rate in different seasons for females.

that except in the zero-group individuals where the specific growth rate is high, the growth is fastest during summer, low during winter and medium during rainy season. Specific growth rate is observed to be highest in the young and later declining with age. This agrees with Medawar's fifth law of growth that " the specific growth rate declines more and more slowly as the organism increases in age " (Brown, 1957) and Minot's (1908) observations that for most animals the specific growth rate is highest early in life and that it typically decreases with increasing age.

SEX RATIO

The proportion of males to females during each month is shown in Table III. The observed differences in the sex ratio during different months were found to be significant, the significance point at 2% level being 22·618. The ratio of males to females during all the months combined was found to be 1 : 1·2,

TABLE III

Distribution of males and females in the samples during different months

Season / Sex	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Male .	187	210	118	330	224	289	367	545	337	1357	913	494	5371
Female	297	267	138	427	263	352	390	634	401	1483	1060	671	6383
Total ..	484	477	256	757	487	641	757	1179	738	2840	1973	1165	11754

LENGTH-WEIGHT RELATIONSHIP

The length-weight relationship for individuals ranging from 23–120 mm. was estimated on the basis of 1968 observations. Sexes were not considered separately since a scatter diagram of weights on lengths (Text-Fig. 8) indicated that there was no sexual difference in length-weight relationship. The mean weights of all the individuals in any particular 3 mm. length range was taken to represent the weight of the midpoint of the class interval. It has been observed that the relationship between length-weight for the species is linear in the logarithmic form and that different relationships exist for the 0-group (*a*) and other individuals (*b*). In both cases the relationship confirms to the general formula.

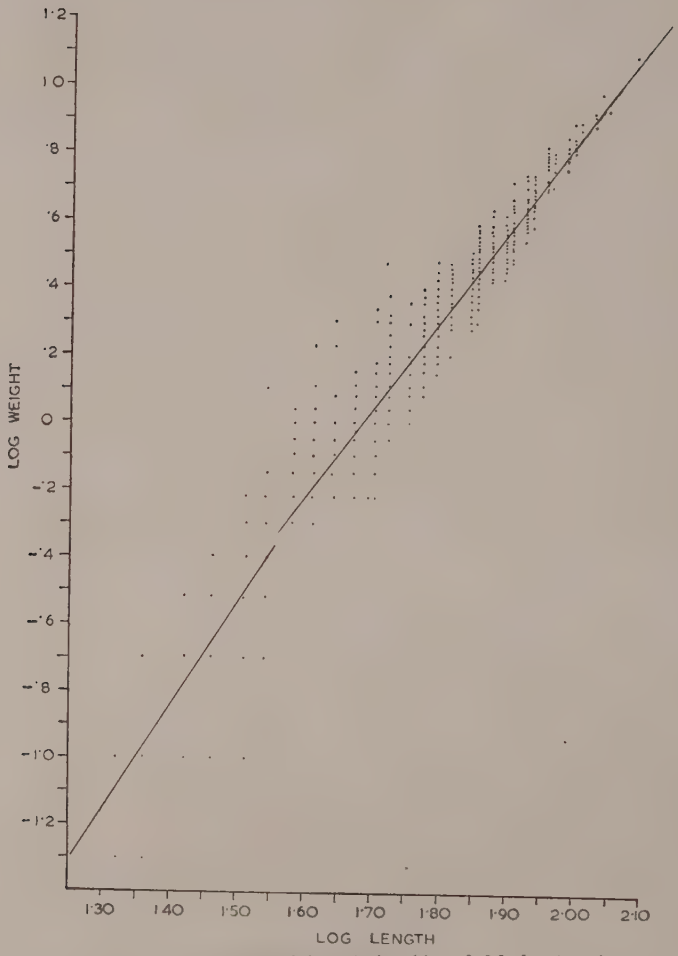
$$W = al^n \quad \text{or} \quad \log W = \log a + n \log L.$$

The relationships for the two groups *a* and *b* were found to be:

(*a*) $\log W = -5{\cdot}0083 + 2{\cdot}9810 \log L$

(*b*) $\log W = -4{\cdot}5407 + 2{\cdot}6976 \log L.$

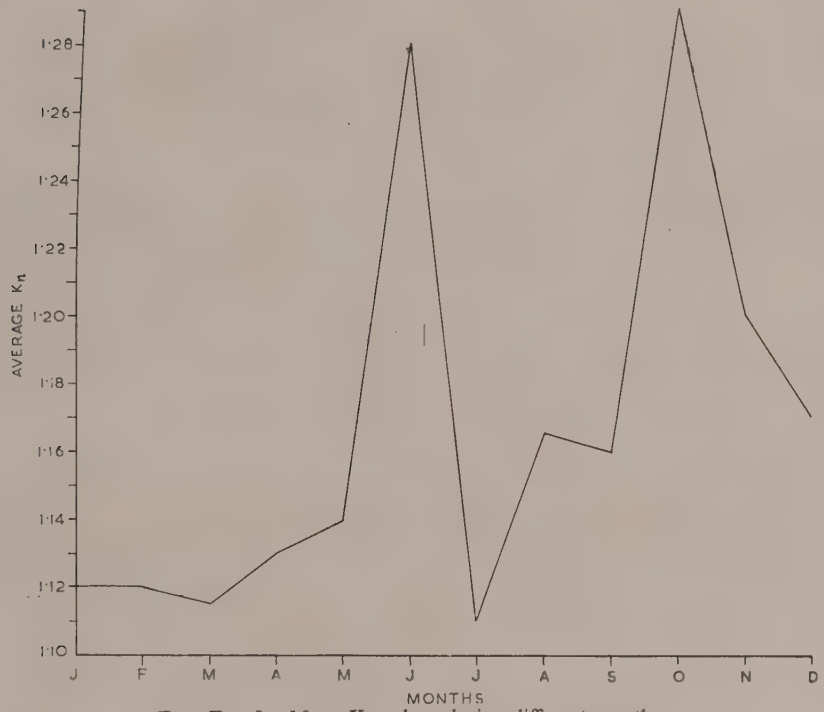
The values of the constant ' *a* ' were found to be significantly different by the application of the ' F ' test. However, the difference in the values of the exponent ' *n* ' (*viz.*, 2·9810 in group *a* and 2·6976 in group *b*) were not found to be significantly different from each other by the same test. It has further been observed that the values of the exponent are not significantly different from 3, hence the species could be said to conform to the so-called cube law,



TEXT-FIG. 8. Length-weight relationship of *M. brevicornis*.

RELATIVE CONDITION

The relative condition factor K_n (Le Cren, 1951) which is a ratio between observed and the smoothed mean weight $(W/\hat{W})$ was calculated separately for each size group, and for all the length groups combined during different months of the year. Sexes of the individuals was not considered separately in the estimation of the K_n since a scatter diagram indicated that sexual differences in condition do not exist. K_n was estimated in preference to ponderal index ($K = 100\ W/L^3$) so as to eliminate the effects of length and correlated

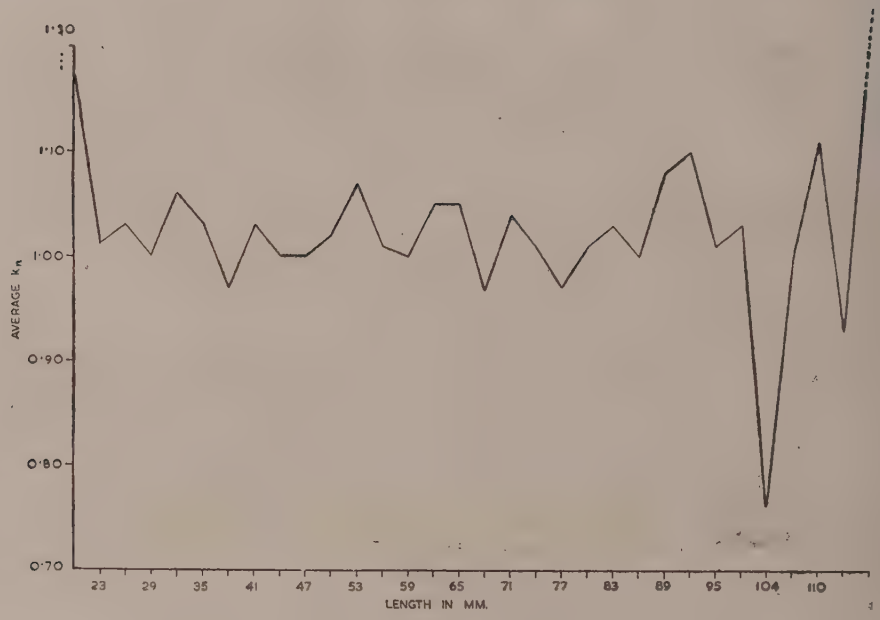


TEXT-FIG. 9. Mean K_n values during different months.

factors on condition particularly since the length-weight relationship was found to vary in different size groups.

Fluctuations in K_n for different length groups indicated (Text-Fig. 10) that condition was high in the smallest size groups (21 mm.). Thereafter, a decline in condition was generally noticeable. Between 23 and 98 mm. moderate fluctuation in K_n, more or less cyclic in nature, were observable. There appears to be abrupt cyclic increases in K_n followed by a slightly less abrupt decline in condition which may probably be attributable to the nature of growth pattern in prawns, where sudden spurts of increase in weight and length take place immediately after moulting and these dimensions remain relatively constant during inter-moulting period. The observed spurts of increase in K_n values indicate, probably, that weight increases, subsequent to moulting, are proportionately greater than increases in linear dimension.

At 98 mm. a marked decline in condition and subsequent recovery higher in magnitude than the fluctuations in earlier size groups, is observable. Such



TEXT-FIG. 10. Mean K_n values per each 3 mm. length interval.

a rapid decline and recovery are generally associated with the attainment of sexual maturity. It is interesting to note that in the case of *M. brevicornis* sexual maturity is usually attained when the prawn is about 100 mm. long.

Studies on the monthly fluctuations (Text-Fig. 9) in K_n indicated that the condition is generally low during the winter months of November to March. The species appears to gradually gain in condition during the summer months till finally in June maximum condition is attained. This is followed by an abrupt fall in K_n during July and subsequent gradual recovery till October when the second maxima in K_n value is reached. It is interesting to note in this context that studies on the seasonal pattern of growth also indicate that growth rate is lowest in the winter months and high in summer and monsoon. A direct correlation between seasonal fluctuations in K_n values and rates of growth is thus evident. The sudden decline in K_n value in July might have been brought about by adverse environmental conditions in the form of sudden decline in salinity and resultant osmotic stress, consequent to the first floods.

Spawning and Migration

Maturing females are represented in the catches only from the lower Sunderbans area (mouth of the estuary) during the months of January–March and the early monsoon period (June-July). Earliest zero-group individuals having modal lengths of 24·5 and 26·5 mm. are obtained in the catches during the periods July and October-November respectively. Soft-shelled females with two prominent white pads covering the surface of the thelycum appear in the catches during December to February and in July. All these evidences probably indicate that the species spawns during March-April once and again in July-August for a second time in the lower reaches of estuary and possibly in the inshore waters.

Generally, immature individuals belonging to the 0, I and II year groups only are represented in the catches in the upper zone and upper reaches of the middle zone of the Hooghly whereas the III year group individuals along with earlier groups occur in lower reaches. As mentioned, maturing and mature females in II to IV stage (Lindner and Anderson, 1956) of gonadial development are met with only in the lower Sunderban area. Larval forms of the species have not been found in the townet collections made at any of the sampling centres during any part of the year. These facts tend to show that spawning takes place in the marine zone of the estuary or inshore areas and the young ones either migrate or are pushed up the estuary by tidal action where they live till the attainment of maturity. Adults appear to migrate to the lower reaches of the estuary where they mature and spawn.

Fishery

M. brevicornis, which contributes to over 30% of the total prawn catches in the Hooghly estuarine system, is one of the most commercially important species of prawns in Bengal. Bulk of the landings of this species is made in the lower zone of Hooghly and lower Sunderbans during the winter months of November–February. In the Matlah estuary, however, the fishery has a longer duration commencing from August and continuing up to next March. Text-Figures 3 and 4 represent the size composition in the commercial catches during different months of the year.

In the lower reaches of upper zone and upper reaches of the middle zone of Hooghly I and II year groups form the fishery, the I year class forming the dominant group, during all the months except August, September and October. In the lower middle zone (Fuleshwar to Nurpur) and lower zone of the Hooghly two additional size groups 0 and III contribute to the fishery

during practically all the months of the year, the 0-group appearing only during the period July–December. In the Roopnarain only 0, I and II year groups contribute to the fishery whereas in Matlah III group also forms the fishery (only during winter) in addition to other groups. The trend of occurrence suggests that bigger size groups are more or less confined to areas of higher salinity.

Gear

Bagnets (Bhinjals and Thorjals), which form the main type of gear with which the species is caught, account for nearly 90% of the total catches of the species and small dragnets and dipnets account for the rest of the landings. Bagnets are generally operated in the midstream either at the subsurface level or in slightly deeper waters. Prawns are known to be bottom feeders inhabiting shallow areas and feeding on debris at the substratum. Hence, it appears possible that operation of suitable prawn nets or traps will enhance, considerably, the catches of bigger and commercially more desirable size groups. Since the present study indicates that bigger size groups are confined to areas of comparatively high salinity, the lower reaches of the estuary might prove to be very profitable prawn fishing grounds provided suitable types of gear, as suggested, are operated.

Summary

The paper deals with growth, migrations, spawning and fishery of *Metapenaeus brevicornis* (M. Edw.) in the Hooghly estuarine system.

Estimates of age and seasonal fluctuations in specific growth rates of the species have been made by the probability plot analysis of length-frequency distributions. There appear to be two-year groups in the catches. Growth in females appears to be faster than in males, during the second year. There are two spawning periods, once in March-April and a second one during June-July. Growth rate is fastest during summer, medium during rainy season and low during winter, in females. Length-weight relationship and relative condition factor K_n have been determined. The probable reasons for the observed seasonal fluctuations and fluctuations in different size groups, of relative condition have been discussed. An account of the distribution of the various year groups in the estuary and migration and fishery of the species is given.

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SOME OBSERVATIONS ON THE CARP FRY RESOURCES OF THE RIVER GODAVARI NEAR RAJAHMUNDRY, ANDHRA PRADESH

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Introduction

Available information on the fish seed resources, particularly of peninsular rivers and the quality and quantity of fish spawn collected therefrom, is rather fragmentary. Chacko (1946) mentions about the spawning of the major carps *Catla catla*, *Labeo fimbriatus*, *Labeo calbasu* and *Cirrhina cirrhosa* in the Godavari and the Krishna from July to September. According to him *Catla* predominates (60%) in the fry and fingerlings collected from the canals and paddy fields; while in the river collections, fry of *L. fimbriatus* (60%) predominate. Alikunhi (1947) recorded the natural occurrence of *Cirrhina mrigala* in the Godavari and found the species forming about 20% of the total fish landings at Rajahmundry. Alikunhi *et al.* (1949) collected eggs and hatchlings of *L. calbasu* in large numbers from the Godavari below the anicut at Bobberlanka, on 22–7–1948. Ganapathi and Alikunhi (1949) in the same year reported the collection of spawn and hatchlings of major carps in large numbers from the Godavari, Tungabhadra, Cauveri, Bhavani and Moyar, all peninsular rivers. Alikunhi and Chaudhuri (1951) collected a single specimen of *Labeo rohita* from the Dhobi tank at Ramachandrapuram (East Godavari District) and inferred that the species naturally occurred in the Godavari, as the Dhobi tank was stocked only with seed collected from that river. Chacko and Ganapathi (1951) while discussing the bionomics of *C. mrigala* from South Indian waters gave details of fry and fingerlings collected in basket traps during September 1949 as follows: *C. catla* 10%, *C. mrigala* 8%, *L. fimbriatus* 10%, *L. calbasu* 2%, *Cirrhina reba* 10%, other miscellaneous carp and minnows 40%, Murrels, Eeels and Cat-fishes 20%. Chacko and Sreenivasan (1955) while describing the hydrobiology of the major South Indian rivers gave an account of the yearly collections of fish seed from the Godavari for the years 1943–44 to 1951–52, not mentioning any details of the species composition.

As a part of a comprehensive programme of investigations on the breeding habits and breeding seasons of the common freshwater fishes of India,

studies were initiated in the river Godavari at Rajahmundry in June 1959. The intensive collections carried out and detailed field observations made during June to October 1959 form the basis of the present communication.

Material and Method

Material for the present study comprises the eggs, larvae and fry of different species of fish collected by operating one fry collection net (large conical net, circumference 9·5 meters at the mouth, 6 meters long, tapering to the cod-end which is open and shaped like a rectangular receptacle; mesh of the cotton material 18 × 18 per 2·5 sq.cm.) in the shallow inundated expanse of the river Godavari near the Andhra Paper Mills at Rajahmundry; about 3·2 kilometers above the railway bridge. Normally the collections lasting for three hours from 6–9 A.M. were made on alternate days but as soon as the collections were found heavy daily observations were resorted to. The samples from the cod-end (*gamcha*) were removed at intervals of five to ten minutes depending on the intensity of the collections and immediately examined in the field when the developing eggs, if any, were first segregated. The sample was then sieved (mesh of sieve 10 × 10 per 2·5 sq.cm.) to separate the larger forms and the debris from the fry which were then transferred to a cloth 'Hapa' fixed in the river. The entire collection made on a particular day was measured in terms of 'spawn cups' and one to two cups brought to the laboratory for accurate enumeration and rearing. About 200–250 fry, constituting a random sample of the day's collection, were reared in glass jars and glass aquaria, where they were fed on live plankton mostly composed of Cladocera, Copepoda and Rotifera, collected from the natural environment. The rearing jars and aquaria were kept clean of debris and freshwater was added when necessary to maintain the water level. Each sample was reared up to identifiable stage (3·0 mm. to 25·0 mm.) and fixed in 5% formalin for subsequent identifications and for determining the species composition of the sample. The specific identification in one or two instances (minor carps) is open to doubt and as the cat-fish fry made up only a very insignificant part, no attempt was made to establish their specific identity.

Observations

Although monsoon season set in by the third week of June, the first flood conditions were observed from 1–7–1959, when carp fry appeared in the collections. For the sake of convenience, the observations made during the period July to October, have been assembled on fortnightly basis and Table I shows the quantity of fish fry collected in each fortnight with other relevant informations.

TABLE I

Details of fortnightly collections of fry per net operated in the river Godavari at Rajahmundry during July to October 1959.

Month and date	Total spawn collected	Average collection per hour	% in monthly total collection	% in total collection of the season	Monthly total collection
July					
1st to 15th ..	127,245	5,302	61·08	42·8	208,299
16th to 31st ..	81,054	3,372	38·92	27·3	
August					
1st to 15th ..	38,783	2,155	70·57	13·0	54,954
16th to 31st .	16,171	770	29·43	5·4	
September					
1st to 15th ..	31,826	1,179	93·78	10·7	33,934
16th to 30th ..	2,108	140	6·22	0·7	
October					
1st to 15th ..	209	17	97·20	0·1	215
16th to 31st ..	6	2	2·80	0·0	

During the month of July there were seventeen collection days with a total of 51 hours of operation when 2,08,299 fry were collected. This gave an average of 4,337 fry per collection hour per net for the month. Samples were very heavy in the first fortnight of July and made up 61·08% of the whole month's collection. The maximum catch of 20,186 fry per hour per net was made on one day (8–7–1959).

In the first half of July *L. fimbriatus* formed 47·43% (Table II) of the catches followed by *C. mrigala*, *C. catla*, *L. rohita* and *L. calbasu* among major carps and *Labeo bata*, *Labeo boga* (?), *Labeo pangusia*, *C. reba*, *Labeo porcellus* (?), *Thynnychthys sandkohl* and others among minor carps. In the second half, however, the samples were not as heavy but *L. fimbriatus* continued to be dominant species (42·18%). The next important species was *C. catla* followed by *C. mrigala*, *L. calbasu* and *L. rohita* and among minor carps *L. bata*, *L. boga* (?), *C. reba*, *T. sandkohl*, *L. pangusia*, *L. porcellus* (?) and others.

The average for the month of August was calculated to be 1,452 fry per net per hour with 70·57% of the entire month's collection made during the

TABLE II

Details of species composition of the season's total collection as revealed on rearing mentioned in percentages

	1-7-1959 to 15-7-1959	16-7-1959 to 31-7-1959	1-8-1959 to 15-8-1959	16-8-1959 to 31-8-1959	1-9-1959 to 15-9-1959	16-9-1959 to 30-9-1959	1-10-1959 to 15-10-1959	16-10-1959 to 31-10-1959
Labeo fimbriatus ..	47·43	42·80	37·90	46·34	36·46	3·08	14·83	..
Cirrhina mrigala ..	10·45	12·08	5·24	8·87	1·37	0·19	1·91	..
Catla catla ..	4·08	13·80	10·72	4·06	13·68	..	0·95	..
Labeo rohita ..	0·04	0·22	1·33	..	..	..	..	..
Labeo calbasu ..	0·02	0·92	0·09	0·14	0·13	..	..	..
Labeo bata ..	28·75	6·06	18·89	7·41	18·36	1·89	1·43	..
Labeo pangusia ..	1·59	2·31	0·74	0·04	0·16	..	..	..
Labeo boga? ..	2·32	5·77	2·07	7·32	0·13	..	..	..
Labeo porcellus? ..	1·38	0·42	0·09	3·47	3·68	1·37	6·69	..
Cirrhina reba ..	1·38	5·54	18·23	16·20	14·81	1·61	16·74	..
Thynnychthys sandkohl ..	1·04	2·41	0·66	1·36	15·84	1·33	..	..
Puntius ambassis ..	0·10	..	1·03	1·33	0·76	14·23	..	..
Puntius sarana ..	..	..	0·10	..	0·24	..	..	..
Puntius sophore ..	..	..	..	0·42	0·16	5·22	..	..
Garra mullayya ..	1·50	7·56	1·32	1·37	1·88	2·28	..	..
Amblypharyngodon mola ..	..	..	0·40	0·66	..	5·31	..	..
Rasbora daniconius ..	..	..	0·14	..	..	..	..	..
Osteobrama cotio ..	..	..	0·20	0·90	0·85	5·41	..	..
Oxygaster ba aila ..	..	..	0·20	0·10	0·24	5·61	9·09	..
Esomus dandrica ..	..	..	..	..	..	5·22	..	..
Barilius barila ..	..	..	..	..	0·69	5·22	16·19	..
Aspidoparia morar ..	..	..	0·64	..	0·56	5·31	6·99	..
Glossogobius giuris ..	..	..	..	..	..	..	..	..
Spratelloides sp. ..	..	..	..	..	..	15·81	7·69	..
Gobius striatus ..	..	..	..	..	..	20·91	17·49	..
Cat-fish fry ..	0·02	0·10	..	..	..	..	..	..
Total collection ..	1,27,245	81,054	38,783	16,171	31,826	2,108	209	..

first fortnight. *L. fimbriatus* continued to be the most dominant species in both halves of the month. Fry of *L. rohita*, which occurred in the catches made in the first fortnight, were however not encountered in the latter half. Among the minor carps, fry of *L. bata*, *C. reba*, *L. boga* (?), *L. pangusia*, *T. sandkohl*, *L. porcellus* (?) and others in the order stated were available in the first half but only *C. reba* (16·20%) and *L. bata* (7·41%) were observed in appreciable quantities in the latter half of the month.

TABLE III

Details of fry collected in the entire season showing percentages of different groups in fortnightly samples

Date	Major carps (%)	Minor carps (%)	Others (%)
1/7 to 15/7	62·02	36·38	1·60
16/7 to 31/7	77·50	22·50	0·00
1/8 to 15/8	55·25	40·38	4·37
16/8 to 31/8	59·74	36·07	4·17
1/9 to 15/9	51·64	42·96	5·40
16/9 to 30/9	3·27	6·21	90·52
1/10 to 15/10	17·70	24·88	57·42
16/10 to 31/10	..	..	..

In September carps were encountered mostly in the first half and *L. fimbriatus* (36·46%) formed the dominant species with *C. catla* making up 13·68% and *C. mrigala* (1·37%). The second half of September and the first half of October gave extremely low quantities of major and minor carps and during the latter fortnight of October, occurrence of fish fry had completely ceased. It may be observed from Table II that the quality of fish fry from the second half of September onwards was extremely poor and larger quantities of fry of minor carps and minnows were available in the collections.

Composition of fry of cultivable species in the total collection from July to October is shown in Table IV.

It is seen that *L. fimbriatus* formed the most dominant species followed by *C. catla*, *C. mrigala*, *L. calbasu* and *L. rohita*. It has to be mentioned however that *L. rohita* and *L. calbasu* formed a very low percentage.

TABLE IV

Species composition of fry of economically important fishes in total collection from July to October 1959

S. No	Species	% in major carp group	% in carp group	% in total collection
1.	*Labeo fimbriatus* ..	68·1	44·6	43·4
2.	*Cirrhina mrigala* ..	14·3	9·3	9·1
3.	*Catla catla* ..	16·8	11·0	10·7
4.	*Labeo rohita* ..	0·4	0·3	0·2
5.	*Labeo calbasu* ..	0·4	0·3	0·3
6.	*Thynnychthys sandkohl*	..	3·1	3·0
7.	*Labeo bata* ..	..	18·2	17·7
8.	*Cirrhina reba* .	..	7·2	7·0
9.	*Labeo pangusia* ..	..	1·4	1·4
10.	*Labeo boga* (?) ..	..	3·3	3·2
11.	*Labeo porcellus* (?)	..	1·3	1·3
12.	Others ..	.	..	2·7

It may be relevant to mention that out of 2,97,402 fry collected in the entire period, about 2,88,288 fry were of eleven commercially important species of carps and percentage of each in different months of collection is given in Table V and the occurrence of these species during the various phases of the fry season graphically represented in Fig. 1.

DISCUSSION

It is well known that an adequate knowledge of the breeding time and periods of the relative abundance of fry of cultivable as well as non-cultivable riverine fish species is of fundamental importance for judicious exploitation of the fish seed resources of the rivers.

TABLE V

Species composition of fry of commercially important species collected from Godavari during the spawn season of 1959

S. No.	Species	July (%)	August (%)	September (%)	October (%)
1.	*L. fimbriatus* ..	46·1	42·2	40·1	34·9
2.	*C. mrigala* ..	11·2	6·6	1·5	4·5
3.	*C. catla* ..	11·0	9·2	14·9	2·2
4.	*L. rohita* ..	0·1	1·0	..	.
5.	*L. calbasu* ..	0·4	0·1	0·1	..
6.	*T. sandkohl* .	1·6	0·9	17·4	..
7.	*L. bata* ..	20·1	16·0	9·3	3·4
8.	*C. reba* ..	3·0	18·4	16·3	39·3
9.	*L. pangusia* ..	1·8	0·6	0·2	..
10.	*L. boga*? ..	3·7	3·9	0·1	..
11.	*L. porcellus*? ..	1·0	1·1	0·1	15·7
	TOTAL ..	2,06,365	52,632	29,142	89

Since the observations on the availability and the behaviour of the occurrence of carp fry must of necessity be continued over many seasons to draw definite conclusions, only some salient trends observed during the present investigations are discussed.

Collection of carp fingerlings from the paddy fields of deltaic areas of the Godavari and the Krishna by basket traps, has been in vogue for considerable years and till recently the State Departments of Fisheries of Madras and Andhra Pradesh exploited this source to meet most of their seed requirements. As the fingerlings are mostly of cultivable species they were directly stocked in the departmental waters.

The stretch of the Godavari, in and around Rajahmundry, is reckoned productive and commercial fishing of considerable magnitude is carried on throughout the year. Among the catches the major carps are represented by *L. fimbriatus*, *C. catla*, *C. mrigala*, *L. calbasu* and minor carps by *L. bata*,

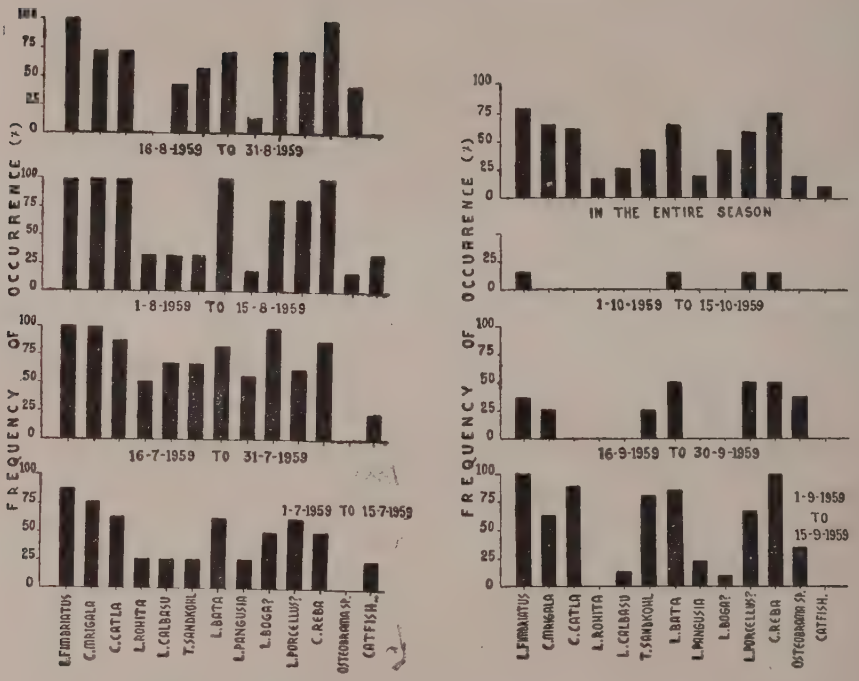

FIG. 1. Histogram showing the frequency of occurrence of fry of commercially important species of freshwater fishes of the river Godavari, represented fortnightly.

Cirrhina sp., *C. reba*, *Puntius sarana*, *T. sandkohl* and *Osteobrama* spp. Catfishes that form a good portion of the commercial catches are represented by *Mystus seenghala*, *Mystus aor*, *Pangasius pangasius*, *Silonia* sp., *Bagarius bagarius*, *Wallago attu*, *Clupisoma garua* and *Ompok bimaculatus*. It may be mentioned that *L. rohita* which has been introduced in the Madras water (Jagannatham, 1946) is also caught occasionally.

From the available data given in the foregoing, it is seen that breeding of carps in the Godavari extends over a maximum period of four months from July to October. In 207 hours of operation during the entire period July to October, a total of about 2,97,402 fry were collected in one net giving an average of approximately 1,436 fry per net per hour although about 20,186 fry per hour per net were recorded on 8–7–1959. The size of fry caught ranged from 4·0–8·0 mm. in total length. The availability of only some stray eggs in the present collections and the fact that size range of fry was between 4·0–8·0 mm. tend to suggest that the actual spawning of carps takes place some distance upstream.

Total collections made in July to October gave 63·69% of major carps, 33·59% of minor carps and 2·72% of others, thus carps alone forming about 97·28% of the collection. Analysis of collections on the fortnightly basis indicated maximum collection of major carps (77·50%) in the second half of July (Table III) followed by 62·02% in the first half of July and thereafter percentage of carp fry decreased. In August the desirable period for collection of major carp fry was the second half of the month when 59·74% was made up by fry of major carps.

L. fimbriatus occurred as a most dominant species in the collections made in July, August and first half of September after which there was a steep fall. Fry of *C. mrigala* and *C. catla* followed a similar pattern of occurrence. *L. rohita* was collected in July and in the first half of August only, while *L. calbasu* in low percentage occurred up to the first half of September. The occurrence of the indigenous carp *T. sandkohl* was maximum in the first half of September while in July and other months it was less frequent. Among the minor carps the occurrence of *L. bata* and *C. reba* was extremely common throughout with the maximum in August. Cat-fish fry in appreciable quantities were present only in July.

Collections were heavy in July with an average hourly collection of 4,337 fry per net as against 1,462 during August and 802 during September. Collections during the first half of July were desirably the best in quantity, averaging 5,302 fry per hour. During the latter half of the month though the collections were less intensive the percentages of major carps particularly of *C. catla* and *C. mrigala* were higher and the collections were therefore of a decidedly better quality than those of the first fortnight.

Sample rearing of fry showed that during the period 22nd July to 31st July, percentage of *C. catla* was the highest for the entire season, averaging 26·0% of the collections of that period. Though the total collection of fry during the first half of July is almost double that of the second half, the number of *C. catla* in the former was less than half the number collected during the second half. For stocking purposes fry with high percentage of major carps are required and hence it is clear that maximum effort should be put to collect as much of the spawn as possible during this period.

Summary

Spawning of carps in 1959 was confined to the months, July to October, in Godavari. Sample rearing revealed that fry of *L. fimbriatus*, *C. catla* *C. mrigala*, *L. calbasu*, *L. rohita*, *C. reba*, *L. bata*, *L. porcellus* (?),

T. sandkohl, *L. boga* (?) and *L. pangusia*, all carp species of commercial importance, were available in appreciable quantities. The most suitable period for collections, as far as quantity is concerned, was the first fortnight in July, but for quality the second fortnight of July. The occurrence of *L. rohita* fry even though in small numbers clearly shows that this transplanted species is now fully established in the Godavari system.

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I am greatly indebted to Dr. B. S. Bhimachar, Director, for his kind encouragement during the course of this work and to Dr. M. P. Motwani for kindly going through the manuscript critically and suggesting various improvements. I wish to express my thanks to the Assistant Director of Fisheries, Rajahmundry, for rendering necessary help in successful execution of this work.

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NOTES ON EGGS, LARVAE AND JUVENILES OF FISHES FROM INDIAN WATERS

XI. Further Observations on the Genus *Auxis* Cuvier

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Introduction

Two species are known under the genus *Auxis* and both have been recorded from Indian coasts (Jones, 1958; Jones and Silas, 1960). Of these the short corseletted form, *A. thazard*, is found in all the warm seas while the long corseletted form *A. thynnoides* is considered to be confined to the Indo-Pacific. However, Matsumoto (1959) has expressed the view that the species occurring on the Atlantic coast of America has a long corselet, which if confirmed, would change considerably our distributional concept of the two species. While there is no doubt about the existence of two species of *Auxis* in the Indo-Pacific, it is obvious that their nomenclature requires further elucidation (Jones and Silas, MS.).

In one of the earlier articles in this series (Jones, 1960) larval stages of *Auxis* sp. and juvenile stages of *A. thynnoides* collected from the seas around India were described. Since then it was possible to examine more material and also re-examine the specimens dealt with in the previous note which have helped to give some indications on the probable distinguishing features of the early stages of the two species.

I have described from the Laccadive Sea (Jones, *op. cit.*) a few stages of *Auxis* measuring from 3·36–7·94 mm. but the specific position was left inconclusive. It was however stated that "Though both the species occur in the Indian waters, so far only *A. thazard* has been recorded from the Laccadive Sea from where these specimens have been collected and the possibility is that the larvae described could be of this species. But the chances of *A. thynnoides* also occurring there are equal and therefore any inference could only be tentative" (Jones, *op. cit.*, p. 341).

The main distinguishing features between the two species are the nature of the corselet scales and the difference in the gill raker counts but these characters are not differentiated in the larval and early juvenile stages

and therefore we have to look in for some other points of difference to distinguish them. Subsequent to the publication of the account cited above, an examination of the larval scombroids collected from the Indian Ocean by the "Dana" Expedition (1928–30) kindly placed at my disposal by the Carlsberg Foundation revealed two kinds of *Auxis* larvae among specimens less than 9 mm. in total length, a comparatively stouter type with the length of the body less than 3 times the head in which the mid-lateral row of chromatophores in the caudal peduncle is prominent and a less stout type with the length of the body about 3 times the head in which the corresponding row of chromatophores in the caudal peduncle is not so prominent. Taking into consideration the juvenile and adult body proportions one is inclined to presume that the former (stouter type) could be *A. thazard* and the latter, *A. thynnoides*. The "Dana" material is being worked out in detail and will be reported on in due course but in the meanwhile the impressions gained as a result of recent studies on the genus *Auxis* are given here to draw the attention of other workers in the subject to problems requiring elucidation.

In this connection attention may be invited to the papers of Matsumoto (1958, 1959) wherein he has distinguished two types of larvae the characters of which were detailed in his second contribution. He had the opportunity to examine fairly extensive material covering the Atlantic (including the Mediterranean and the Gulf of Mexico), the Pacific and parts of the Indian Ocean. The distinguishing features referred to by him (Matsumoto, 1959) are more or less applicable to the two types of larval *Auxis* examined by me from the Indian Ocean.

Type I *Auxis* larvae are the stouter of the two kinds described by Matsumoto (*op. cit.*) and these could be considered as *A. thazard*. Actually, he had, in his earlier paper, assigned all of them except one under the above species. As regards *Auxis* type II which are comparatively elongated, they appear to belong to *A. thynnoides*. The same could be said of the larvae described by Wade (1951) from the Philippine Sea. It would appear that the long corseletted species *A. thynnoides* (= *A. tapeinosoma* of Wade) is very common in the Philippine waters. Mead (1951) has figured two specimens under *A. thazard* collected from the Pacific Coast of Central America which appear to belong to the stouter category. Yabe and Ueyanagi (1961) have described a 6·2 mm. larva of *A. tapeinosoma* (= *A. thynnoides*) from the Pacific. Mention may be made here of the 4 mm. specimen which was tentatively placed under *Auxis* by Kishinouye (1926). Though the figure is not quite clear it appears to resemble the stouter type. The only important work outside the Indo-Pacific on *Auxis* larvae is by Ehrenbaum (1924)

who has described a number of larvae from the Mediterranean under *A. thazard*. Here also we are confronted with indefiniteness since all the stages given by him under Fig. 8 except one, *viz.*, 8 *e*, appear to belong to the elongated type in which case they should be *A. thynnoides*. We have therefore to find out the correct identity of the species of *Auxis* occurring in the Atlantic and the Mediterranean as rightly pointed out by Matsumoto (1959).

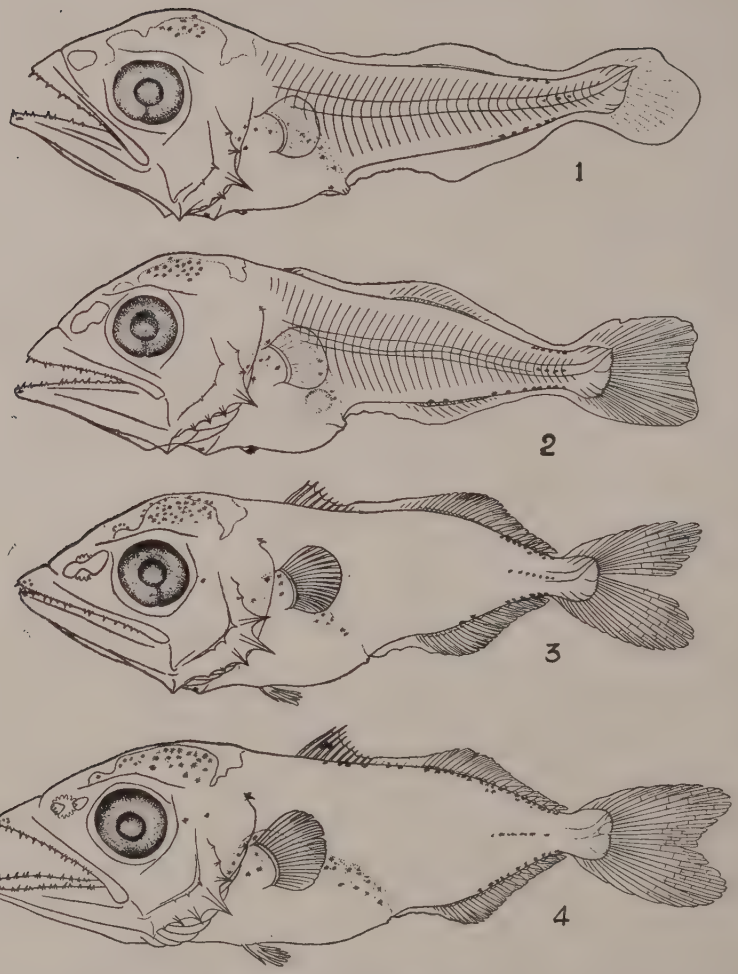
The contributions of Sanzo (1909) and Mito (1961) relate to very early stages and are therefore not discussed here.

On the above basis of separation of the two species it is found that in the Indian Ocean material examined by me larval *Auxis thazard* is more widely distributed than *A. thynnoides* which are comparatively fewer in number and are confined only to some areas close to the African Coast (Jones and Kumaran, MS.). The hauls taken from the Dana Station No. 3946 (lat. 3° 26′ S., long. 42° 58′ E.) on 3–1–1930 were most rich in larval *Auxis*, both species of which were found in the collections. A few stages belonging to the two types are briefly described here. Detailed descriptions are not attempted since figures and body measurements are given. Though the specimens were in a fairly good state of preservation the chromatophores appear to have faded to some extent in many on account of long preservation and therefore their correct depiction have become difficult. The figures therefore may not be quite comparable in the above respect with those drawn from fresh material.

Auxis thazard Lacépède

The size range of *A. thazard* in the collection is from about 4–15 mm. Of the above, 5 stages measuring 4·97 mm., 6·58 mm., 8·78 mm., 10·25 mm. and 14·42 mm. in total length are figured and some of the salient features are pointed out, drawing attention to existing descriptions of comparable stages recorded from the Indo-Pacific.

4·97 *mm. larva* (Fig. 1).—This stage though slightly larger is somewhat comparable to the 4·5 mm. larva described and figured by Matsumoto (1958) first as *A. thazard* and subsequently (Matsumoto, 1959) under *Auxis* type I and the 4·4 mm. stage of *Auxis* sp. described by me from the Laccadive Sea (Jones, 1960). In the Dana specimen the pelvic fins could be seen as small projections on the ventral side immediately behind the symphysis of the pectoral girdle. In other respects it is similar to those described by earlier workers.



FIGS. 1–4. Larval stages of *Auxis thazard*. Fig. 1. 4·97 mm. (lower jaw partially reconstructed). Fig. 2. 6·58 mm. (the stomach appears distended due to some fish larva it had eaten, the eye of which is faintly visible as a dark circular patch). Fig. 3. 8·78 mm. Fig. 4. 10·25 mm.

6·58 *mm. larva* (Fig. 2).—The nearest corresponding stage in the earlier descriptions is the 7·05 mm. larva by Matsumoto (1958) from the Pacific which he first gave under *A. thazard* and subsequently under *Auxis* type I (Matsumoto, 1959). The anterior spines of the first dorsal have begun to appear at this stage in the specimen under description. They are how-

TABLE I

Measurements of Auxis thazard *larvae in mm. from "Dana" Station No.* 3946 (*lat.* 3° 26′*S., long.* 42° 58′ *E.*) *collected on* 3–1–1930

Sl. No.	Station	T.L.	St.L.	Head	Max.W.	Snout	Eye	Sn. to D.	Sn. to vent
1	3946 III	4·97	4·39	1·62	1·36	0·62	0·57	1·93	2·35
2	,,	6·58	5·75	2·25	1·93	0·83	0·68	2·51	3·24
3	,,	8·78	7·47	3·40	2·51	1·30	0·99	3·40	4·60
4	,,	10·25	8·53	3·71	2·77	1·38	1·04	4·02	5·69
5	,,	14·42	12·05	4·50	3·50	1·72	1·30	5·13	7·84

ever not present in the 6·8 mm. larva of *Auxis* described by Wade from the Pacific and which is now presumed to be *A. thynnoides.*

8·78 *mm. larva* (Fig. 3).—There is no stage described earlier which could be considered comparable to this. This comes in between the 9·7 mm. stage described by Matsumoto (1958 and 1959) and the 7·94 mm. larva recorded by me from the Laccadive Sea (Jones, 1960). The resemblance between the "Dana" specimen and the one described by Matsumoto (*op. cit.*) is striking. In both the first dorsals are devoid of chromatophores and the preanal length of the body exceeds the postanal length.

10·25 *mm. larva* (Fig. 4).—This stage is comparable to the 11·2 mm. stage described and figured by Matsumoto (*op. cit.*) and the 11·5 mm. stage described by Mead (1951). The spinous dorsal shows pigmentation and the dorsal row of chromatophores have extended to the base of the first dorsal. The snout shows two distinct nasal apertures on each side and teeth are larger and more in number than in the previous stage. The vent has shifted posteriorly making the preanal conspicuously longer. The longest preopercular spine at this stage continues to project beyond the operculum. After reaching a length of about 11 mm. there appears to be a distinct elongation of the body.

14·42 *mm. larva* (Fig. 5).—The only description of *Auxis* larva nearest to this size is of the 13·2 mm. larva described by Matsumoto (1959). The

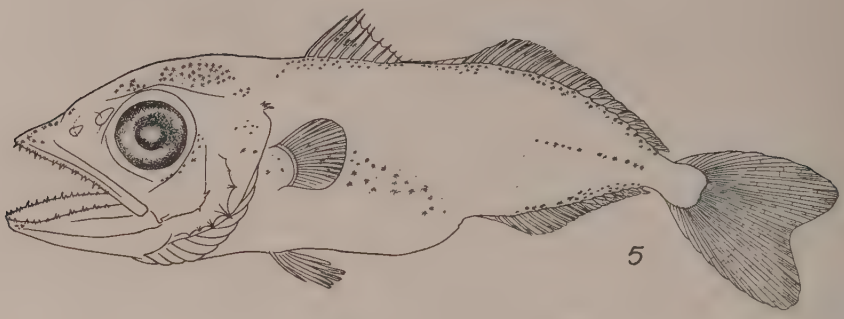


FIG. 5. *Auxis thazard* larva 14·42 mm.

anterior portion of the body, especially the abdominal region, has elongated considerably and the vent comes to be situated nearly in line with the origin of the second dorsal. There is an appreciable increase in chromatophores. The preopercular spines are reduced in size and the longest hardly projects beyond the operculum.

Larvae older than the above which could almost be considered as early juveniles have been described by Mead (1951) and Matsumoto (1959). They measure 18·0 mm. and 25·0 mm. respectively.

Auxis thynnoides BLEEKER

The sizes of larvae in the "Dana" collection presumed to belong to *Auxis thynnoides* appear to range from about 4 mm. to nearly 9 mm. According to Matsumoto (1959) the series of specimens belonging to *Auxis* type II which I consider to be *A. thynnoides* "stops at 8 mm., and all specimens above this size are referable to type I" (Matsumoto, *op. cit.*, p. 25). It is interesting that the situation is more or less the same with regard to the "Dana" material studied by me from the Indian Ocean.

4·46 *mm. larva* (Fig. 6).—This stage is more or less comparable to the 5·1 mm. larva described by Wade (1951) and the 5·2 mm. larva described by Matsumoto (*op. cit.*). The difference between this and 4·5 mm. *Auxis* type I larva of Matsumoto (1959) and 4·40 mm. larva of Jones (1960) which are now presumed to be *A. thazard* is striking.

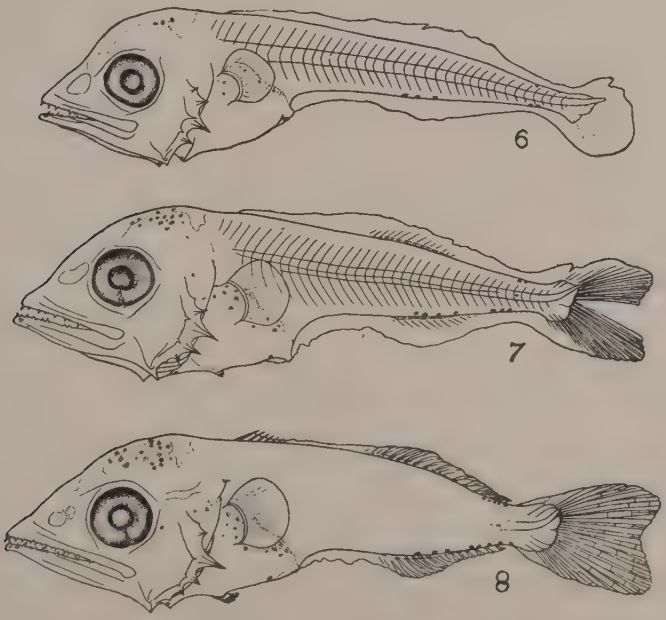
6·54 *mm. larva* (Fig. 7).—This is comparable to the 6·8 mm. larva described by Wade (1951) and to some extent to the 7·2 mm. *Auxis* type II larva of Matsumoto (*op. cit.*). Pigmentation on the body is much less than in the *thazard* type of larvae of corresponding size described by Matsumoto (1959) and Jones (1960).

TABLE II

Measurements of Auxis thynnoides *larvae in mm. from "Dana" Station No.* 3946 (*lat.* 3° 26′ *S., long.* 42° 58′ *E.*) *collected on* 3–1–1930

Sl. No.	Station	T.L.	St.L.	Head	Max.W.	Snout	Eye	Sn. to D.	Sn. to vent
1	3946 I	4·66	4·34	1·41	1·30	0·42	0·42	1·72	1·98
2	3946 II	6·54	5·64	1·93	1·72	0·73	0·63	2·25	2·83
3	3946 I	8·68	7·77	2·77	2·19	1·09	0·89	2·98	3·82

8·68 *mm. larva* (Fig. 8).—No larva of comparable size has been described earlier which could be placed under *A. thynnoides*. Except for the shorter length of head and comparatively less pigmentation it is difficult to distinguish the specimen from *thazard* type of larva.



FIGS. 6–8. Larval stages of *Auxis thynnoides*. Fig. 6. 4·66 mm., Fig. 7. 6·54 mm. Fig. 8. 8·68 mm.

It is interesting that recent studies on *Auxis* larvae by different workers have brought to light the presence of two types distributed in all the three oceans. On the basis of existing knowledge what they actually represent could only be a conjecture and the need for further investigations especially towards the correct determination of the species under the genus and their distribution is indicated. The identification of the larvae described in this note is therefore only provisional.

My previous note (Jones, *op. cit.*) dealt with 26 juvenile specimens collected from Vizingam near Trivandrum on the west coast of India which were placed under *A. thynnoides*. From a re-examination of the above material it would appear that serial numbers 1 to 14 given under Table II on page 342 of the above paper cannot be assigned with any extent of definiteness to *A. thynnoides* as has been done, while there is no doubt about the identity of the rest of the specimens as both the nature of the corselet scales and gill raker counts show that they belong to *A. thynnoides*. There is a size difference of about 50 mm. between the two lots and in the absence of intermediate stages it would be more appropriate to place the first 14 specimens under *Auxis* sp. rather than under *A. thynnoides*. In fact, in the absence of scales if we rely on the gill rakers alone, which appear to develop early in both the species, one will even be inclined to place them under *A. thazard*.

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PROXIMATE AND MINERAL COMPOSITION OF FRESHWATER FISHES

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Data on chemical composition of many of the freshwater fishes of our country is not available and hence an attempt has been made to analyse as many as thirty-six species. The chemical composition of fish varies widely from species to species and season to season. There is also individual variation in the same species. A knowledge of chemical composition is essential in order to compare its value as food with other protein foods. Stansby (1954) has elaborated on the importance of chemical analysis.

It is also necessary to have data on the composition of fish in order to make the best use of them as food and in order to develop the technology of processing fish and fish products. It has also a bearing on culinary techniques. Madras State has intensified fish cultural activities in Inland waters to augment the animal protein supply to the population. Introduction of indigenous and exotic fast-growing species in the newly formed impoundments is a major step in this direction. The fishes from Bhavanisagar Reservoir and Mettur Reservoir have been analysed for their composition.

Chari (1948) has tabulated the proximate and mineral composition of marine species of West Coast of Madras while that of freshwater fishes of Bengal has been furnished by Saha and Guha (1939) and Basu and De (1938). No account is available about the freshwater fishes of Madras State. Limitations in tabulating the data on chemical composition of fish which exhibit very wide variations have been pointed out by Stansby (1954) and we will be dealing with this aspect in another publication. That there is no variation between the left and right fillets of dover sole and rock fish in moisture, oil or protein has been proved by Sinnhuber *et al.* (1956). However a comparative data as the one furnished by Thurston *et al.* (1959) for freshwater fishes of North America are deemed useful.

Experimental

Collection of Specimens.—All the specimens for analysis have been collected in and around Bhavanisagar and Mettur Dam. They were taken up

for analysis soon after their capture when they were in fresh condition. The time lapse between the hour of capture and analysis is about two hours but has never exceeded five.

Sampling.—Before sampling the fish were measured, weighed, skinned, the edible portion is separated, weighed and then minced well in a meat mincer. For minnows and smaller fishes the entire fish is taken as a whole and minced well. A portion of the well-minced sample is taken up for finding out the moisture, fat, protein, ash, phosphorus, calcium and iron content. The moisture is determined by drying the flesh at 105° C. for 5–6 hours to constant weight. The fat is estimated by extracting the same with ether in a soxhlet extractor for a period of 10–12 hours or more. Nitrogen in the flesh is estimated by micro-kjeldhal nitrogen estimation method and the nitrogen value is multiplied by the factor 6·25 for protein value. The ash content is estimated by igniting a known weight of the dried substance.

Phosphorus is estimated volumetrically by precipitating it with ammonium molybdate and then dissolving the precipitate in standard alkali and then titrating the excess of alkali with standard acid.

Calcium is estimated volumetrically by precipitating it with ammonium oxalate, dissolving it in 1 : 4 sulphuric acid and titrating against standard permanganate.

Iron is estimated colorimetrically by comparing the colour produced with ammonium thiocyanate in a Klett Summerson photoelectric colorimeter after extracting the colour with amyl alcohol.

Results and Discussion

The data are treated conveniently under the following heads:

(1) Physical data, (2) Proximate composition and (3) Phosphorus, calcium and iron content.

The length-weight relationship gives some idea about the condition of fish taken up for analysis. The individual fish used for analysis weighed from 5–5,000 gm. The percentage of edible portion obtained from different species varied between 30 and 50%. It can be safely said that about 35% of a fish is edible.

Variation in Proximate Composition

The analytical data indicate wide variation in the moisture, protein and fat content, between different species. The moisture content in general has

TABLE I

Physical data of freshwater fishes

	Scientific name of the fishes	Locality	Family	Dates of analysis	Length mm.	Weight gm.	Percentage edible matter
1.	*Barbus hexagonolepis*	Bhavanisagar	Cyprinidae	31- 7-1956	380	600	46
2.	*Barbus dubius* ..	Do.	Do.	28- 9-1956 to 12- 5-1960	320-560	340-2030	45
3.	*Barbus carnaticus*	Do.	Do.	8-11-1956	275	380	45
4.	*Barbus chrysopoma*	Do.	Do.	6- 7-1957	250	285	38
5.	*Barbus tor* ..	Do.	Do.	11-1 -1957 to 18-11-1960	360-710	485-4858	48
6.	*Labeo kontius*	Do.	Do.	8-10-1956 to 23- 4-1959	240-340	175-560	47
7.	*Labeo fimbriatus*	Do.	Do.	26- 1-1957 to 29-10-1958	380-520	450-3400	48
8.	*Labeo paral* ..	Mettur Dam	Do.	29-10-1958	330	280	45
9.	*Labeo calbasu* ..	Do.	Do.	29-10-1958 to 24- 8-1960	300-580	350-2050	41
10.	*Cirrhina reba*	Bhavanisagar	Do.	17- 9-1956	160-205	180	36
11.	*Cirrhina mrigala*	Do.	Do.	21-12-1956	416	1020	31
12.	*Cirrhina latea* (?)	Do.	Do.	11- 1-1957	462	1005	48
13.	*Cirrhina cirrhosa*	Do.	Do.	30- 9-1957 to 22- 7-1960	430-520	910-1590	42
14.	*Cyprinus carpio* var. *vulgaris*	Ooty	Do.	22- 7-1958	328	390	49
15.	*Cyprinus carpio* var. *specularis*	Do.	Do.	22- 7-1958	595	1135	40
16.	*Carassius vulgaris*	Do.	Do.	13- 9-1958	295	230	35
17.	*Wallago attu*	Bhavanisagar	Siluridae	18-10-1956 to 25- 2-1959	270-840	115-2720	40
18.	*Macrones aor*	Do.	Do.	11- 7-1956 to 10- 2-1959	330-780	390-2830	41

TABLE I (*Contd.*)

	Scientific name of the fishes	Locality	Family	Dates of analysis	Length mm.	Weight gm.	Percentage edible matter
19.	*Macrones punctatus*	Bhavanisagar	Siluridae	10– 1–1957	450	565	43
20.	*Macrones seenghala*	Mettur Dam	Do.	30–10–1958	470	350	43
21.	*Silonia silundia*	Do.	Do.	30–10–1958	500	910	50
22.	*Pangasius pangasius*	Do.	Do.	30–10–1958 to 22– 7–1960	470–582	680–2275	48
23.	*Callichrous bimaculatus*	Do.	Do.		100–112	30	..
24.	*Mastacembelus armatus*	Bhavanisagar	Rhyncob-dellidae	23– 4–1958 to 30–10–1958	500–572	170–350	48
25.	*Anguilla* sp.	Do.	Muraenidae	9–10–1958	610	380	37
26.	*Notopterus kapirat*	Do.	Notopteridae	3– 1–1958	240–248	420	30
27.	*Scaphiodon brevidorsalis* (?)	Do.	Cyprinidae	18– 4–1957	250	315	36
28.	*Catla catia*	Do.	Do.	4– 3–1957 to 23– 4–1959	210–630	120–3650	33
29.	*Etroplus suratensis*	Do.	Chromides	5– 3–1958	121	150	32
30.	*Osphronemus goramy*	Do.	Osphronemi-dae	30–10–1958	270	225	40
31.	*Tilapia mossambica*	Do.	Cichlid	7–11–1956 to 23– 2–1960	134–275	34–380	45
32.	*Ophiocephalus* sp.	Do.	Ophiocephali-dae	3– 8–1958	590	800	43
33.	*Danio malabaricus**	Do.	Cyprinidae	4– 8–1958	60–90	25	..
34.	*Rasbora daniconius**	Do.	Do.	3– 9–1958	65–102	28	..
35.	*Chela clupeoides**	Do.	Do.	9– 1–1959	44–56	16	..
36.	*Salmo irideus*	Nilgiris	Salmonidae	7– 1–1961	316–356	315–440	48

* *Note.*—1. As the fishes were too small the percentage edibility was not determined.

2. In cases where more than one fish has been analysed, the range of length and weight is given.

TABLE II

Composition data of freshwater fishes

	Scientific name of the freshwater fishes	% of Moisture	% of Fat	% of Protein	% of Ash
1.	*Barbus hexagonolepis* ..	78·2	0·25	18·8	1·17
2.	*Barbus dubius* ..	72·6–80·5	0·30–7·20	15·9–19·3	0·93–1·61
3.	*Barbus carnaticus* ..	78·3	1·0	16·9	1·23
4.	*Barbus chrysopoma* ..	75·0	3·94	18·7	1·44
5.	*Barbus tor* ..	79·2–80·0	3·0 –3·9	14·4–17·6	1·12–1·9
6.	*Labeo kontius* ..	75·8–77·8	0·99–1·66	15·9–17·4	1·68–1·94
7.	*Labeo fimbriatus* ..	59·8–78·9	0·44–10·0	17·2–19·0	1·05–1·3
8.	*Labeo paral* ..	74·2	1·95	18·9	1·78
9.	*Labeo calbasu* ..	74·6–76·3	2·3 –3·2	19·1–19·6	1·06–1·95
10.	*Cirrhina reba* ..	77·5	1·2	19·5	1·23
11.	*Cirrhina mrigala* ..	73·0	2·55	18·1	1·69
12.	*Cirrhina* species (*latea*) (?)	72·6	1·6	18·1	1·23
13.	*Cirrhina cirrhosa* ..	67·9–80·2	0·27–10·1	18·2–20·1	1·24–1·32
14.	*Cyprinus carpio* (var. *vulgaris*)	73·7	6·9	18·2	1·18
15.	*Cyprinus carpio* (var. *vulgaris*	78·0	0·51	17·6	1·58
16.	*Carassius vulgaris* (Golden carp)	83·6	0·26	13·5	0·92
17.	*Wallago attu* ..	77·2–81·9	0·17–1·97	15·8–18·9	0·86–1·45
18.	*Macrones aor* ..	76·0–82·5	0·21–4·55	14·9–19·0	0·81–1·58
19.	*Macrones punctatus* ..	80·0	0·57	16·8	1·07
20.	*Macrones senghala* ..	72·6	1·3	18·2	1·13
21.	*Silonia silundia* ..	72·9	1·8	18·1	1·27
22.	*Pangasius pangasius* ..	78·3–79·5	0·69–2·4	16·8–17·5	1·06–1·13
23.	*Callichrous bimaculatus**	75·2	1·97	16·1	3·27
24.	*Mastacembelus armatus* ..	74·8–77·9	1·8 –4·44	16·6–17·7	1·17–1·21
25.	*Anguilla* sp. ..	72·1	6·97	18·3	1·20
26.	*Notopterus kapirat* ..	76·5	0·68	18·0	1·13
27.	*Scaphiodon* species (*brevidorsalis*) (?)	75·0	4·24	19·0	1·29
28.	*Catla catla* ..	78·8–80·9	0·55–6·78	17·4–17·8	1·2 –1·92
29.	*Etroplus suratensis* ..	79·7	1·65	17·5	1·08
30.	*Osphronemus gorami* ..	73·9	1·6	18·4	1·62
31.	*Tilapia mossambica* ..	76·4–82·8	0·30–2·06	14·5–19·1	0·88–1·56
32.	*Ophiocephalus marulius* ..	78·5	3·74	19·4	1·65
33.	*Danio malabaricus** ..	75·5	2·5	16·1	5·14
34.	*Rasbora daniconius** ..	75·1	3·32	15·6	3·88
35.	*Chela clupeoides** ..	76·8	3·68	13·7	3·59
36.	*Salmo irideus* ..	78·9–80·5	1·58–2·09	14·6–14·8	1·22–1·3

* *Note*; These fishes have been analysed as a whole.

TABLE III

Phosphorus, calcium and iron in freshwater fishes

	Scientific name of the freshwater fishes	% of Phosphorous (P_2O_5)	% of Calcium (CaO)	% of Iron (Fe)
1.	*Barbus hexagonolepis* ..	0·89	0·13	14·9
2.	*Barbus dubius* ..	0·43–0·81	0·11–0·30	4·1 –9·8
3.	*Barbus carnaticus* ..	0·62	0·18	6·2
4.	*Barbus chrysopoma* ..	0·62	0·29	9·9
5.	*Barbus tor* ..	0·56–0·61	0·13–0·28	6·3 –9·6
6.	*Labeo kontius* ..	0·68–0·69	0·27–0·34	8·4 –11·4
7.	*Labeo fimbriatus* ..	0·48–0·62	0·12–0·18	8·4 –11·4
8.	*Labeo paral* ..	0·64	0·35	9·4
9.	*Labeo calbasu* ..	0·52–0·82	0·19–0·26	6·6 –12·0
10.	*Cirrhina reba* ..	0·52	0·26	6·3
11.	*Cirrhina mrigala* ..	0·51	0·13	7·2
12.	*Cirrhina* species ..	0·54	0·18	7·7
13.	*Cirrhina cirrhosa* ..	0·50–0·66	0·20–0·36	5·2 –9·2
14.	*Cyprinus carpio* (var. *vulgaris*) Scale carp	0·53	0·21	5·2
15.	*Cyprinus carpio* (Specularis) Mirror carp	0·57	0·13	7·6
16.	*Carassius vulgaris* ..	0·47	0·10	4·2
17.	*Wallago attu* ..	0·41–0·60	0·10–0·17	4·2 -8·5
18.	*Macrones aor* ..	0·37–0·72	0·11–0·23	4·2 –5·8
19.	*Macrones punctatus* ..	0·42	0·13	4·9
20.	*Macrones senghala* ..	0·52	0·17	7·8
21.	*Silonia silundia* ..	0·51	0·14	7·1
22.	*Pangasius pangasius* .	0·51–0·53	0·19–0·20	6·0 –7·0
23.	*Callichrous bimaculatus* ..	1·3	1·37	11·3
24.	*Mastacembelus armatus* .	0·52–0·59	0·15–0·21	5·6 –6·8
25.	*Anguilla* sp. ..	0·57	0·18	11·7
26.	*Notopterus kapirat* ..	0·54	0·21	6·2
27.	*Scaphiodon* species ..	0·71	0·17	10·0
28.	*Catla catla* ..	0·50–0·77	0·19–0·20	4·99–17·0
29.	*Etroplus suratensis* ..	0·50	0·15	4·9
30.	*Osphronemus gorami* .	0·64	0·31	8·0
31.	*Tilapia mossambica* ..	0·45–0·64	0·12–0·28	4·4 –10·8
32.	*Ophiocephalus marulius* ..	0·46	0·17	9·8
33.	*Danio malabaricus* ..	2·4	2·66	7·7
34.	*Rasbora daniconius* ..	1·9	1·93	9·2
35.	*Chela clupeoides* ..	1·6	1·85	6·3
36.	*Salmo irideus* (Rainbow trout)..	0·44	0·09	13·6

been found to be between 75 and 80% even though it was as low as 59·8% in the case of *Labeo fimbriatus* and as high as 83·6% in the case of *Carassius vulgaris*. The fat content varied inversely with moisture content. In general, the fat content of freshwater fishes has been found to be invariably low but at times, in individual specimens it has been as high as 20%.

The protein content in most of the cases has been found to be between 17 and 18% even though in rare cases it has been found to be as low as 13·5% or as high as 20·1%. The ash content in general was found to be between 1 and 1·5%. It has been found to be more than 3% when the fish is taken as a whole for analysis. The above data compares favourably in general with the data of Thurston *et al.* (1959) for the freshwater fishes of the United States. The highest ash content for the United States fishes was 1·48% and the lowest 0·41% in contrast to a slightly higher figures of 1·95 and 0·81% respectively for the fishes analysed by us. The lowest protein content of 13·5% and the highest moisture content of 83·6% was found in the Golden carp (*Carassius vulgaris*) which was starving. Similar results have been obtained by Phillips *et al.* (1960) in the case of starving brook trout. The data for the composition of Bengal fishes of species, *Cirrhina mrigala*, *Notopterus*, *Catla catla*, *Wallago attu* and *Labeo calbasu* (Saha *et al.*, 1939) differ from the data for the same species tabulated by us. This is to be expected (Thurston *et al.*, 1959).

Summary

Composition of 36 species of freshwater fishes has been determined and tabulated. A comparison has been made with the data furnished by other authors.

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OBSERVATIONS ON SOME ASPECTS OF SPOILAGE IN FRESH AND FROZEN PRAWNS

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Introduction

The prawn freezing factories in Cochin receive their supplies of raw materials from all over the West Coast. Some factories have separate peeling centres in most of these places and the prawns collected from nearby fishing villages are peeled and deveined or beheaded and deveined as the case may be, cleaned and packed in ice at these centres before transporting to the factories. It often happens that the material thus transported takes more than 24 hours to reach the factories. Icing of the material at the peeling site helps in preventing bacterial spoilage during the long period of transport. But the success of icing will largely depend on the amount of ice used and how it is applied. If the requisite quantity of ice is not used the material will not only be not cooled to the desired level but its temperature will rise up during the long trip to the factory creating favourable conditions for normal spoilage processes to continue.

Supplies arrive at the factories at all times. Those that are received late in the evening will be kept in chill storages at temperatures ranging from 30–35° F. until taken up for further processing. Although this will help in keeping down bacterial multiplication a lot of other biochemical changes can proceed uninterrupted (Shewan, 1949). There is in addition the inevitable delay during the various stages of processing like washing, grading, packing and freezing. During all these stages the material is likely to undergo spoilage if sufficient care is not taken to keep down its temperature to around 32° F. and to minimise the time taken for each process.

The present communication deals with the results of an enquiry into the changes taking place in the chemical and bacteriological characteristics of prawns during the various stages of processing. A correct knowledge of these changes is highly essential in judging the quality of the final product as well as in establishing control measures to improve the quality of frozen prawn products.

Experimental

The experiments were carried out with the co-operation of some of the leading prawn freezing factories in Cochin. Samples were collected from different lots of raw materials as they arrived at the factories. As far as possible care was taken to follow the same lots through different stages of processing until finally frozen. Side by side with this a study was also made on the changes taking place in fresh prawn samples collected from landing places during spoilage at room temperatures. This was found necessary for the proper interpretation of the results obtained with the factory samples. All the samples were tested for their chemical and bacteriological characteristics. The changes in the pH, trimethylamine, total volatile nitrogen, non-protein nitrogen, *a*-amino nitrogen and viable bacterial count of fresh prawn during spoilage under laboratory conditions are presented in Table I. Table II gives the data collected on ' headless ' prawns during different stages of processing while the corresponding figures for peeled, deveined and frozen prawns are presented in Table III. The changes in the quality of three different packs of frozen prawns, *viz.*, headless, peeled and deveined and cooked frozen, during storage for a period of 13 weeks have also been studied and the results are given in Table IV. The variations in the pH of a few

Table I

Changes in the chemical and bacteriological characteristics of prawn during spoilage at room temperatures

Description of sample	Period of storage	T.M.A. mg. N%	T.V.N. mg. %	*a*-amino N mg. %	pH	Non-protein N mg. %	$HgCl_2$ test	Viable bacterial count/gm.
Metapenaeus monoceros	2 hours	2·8	13·27	277·0	6·50	..	−ve	$8·8 \times 10^4$
	5 hours	2·8	13·27	275·4	6·50	..	− ve	$5·3 \times 10^5$
Palaemon sp.	Fresh	Nil	8·40	226·8	6·60	..	− ve	$4·0 \times 10^3$
	5 hours	1·36	12·88	261·1	6·71	..	− ve	$1·0 \times 10^4$
	24 hours	.	.	..	7·45	..	+ve	$8·0 \times 10^7$
Parapenaeopsis stylifera	4 hours	2·65	8·41	155·2	6·60	..	Doubtful	..
	8 hours	3·40	12·92	170·1	6·70	618·4	+ve	..
Metapenaeus dobsoni	6 hours	2·05	20·54	117·5	6·80	502·5	+ve	$2·4 \times 10^6$
	10 hours	10·29	31·57	109·1	7·70	703·0	+ve	$1·6 \times 10^8$

TABLE II

Changes in the chemical and bacteriological characteristics of 'headless' prawns during different stages of processing

Description of sample	T.M.A. mg. N%	T.V.N. mg. %	*a*-amino N mg. %	Non-protein N mg. %	Bacterial count/gm.
Series I*					
Initial ..	2·8	11·9	97·05	728·0	$1·0\times10^{7}$
Stored in chill room for 18 hours ..	2·8	10·5	107·40	616·0	$1·3\times10^{6}$
After freezing ..	5·6	15·4	97·05	1,008·0	$3·6\times10^{4}$
Series II					
Initial ..	3·2	13·6	..	..	$3·2\times10^{5}$
Stored in chill room for 14 hours	2·8	11·2	..	..	$1·7\times10^{5}$
After washing ..	2·8	11·2	..	..	$7·5\times10^{4}$
After freezing ..	..	..	..	..	$3·8\times10^{4}$
Series III					
Initial ..	2·1	11·9	..	..	$4·1\times10^{5}$
After washing ..	2·1	9·8	..	..	$7·0\times10^{4}$
After freezing ..	1·4	6·3	..	..	$1·4\times10^{4}$

* All the samples belonged to the *Palaemon* sp.

TABLE III

Changes in the chemical and bacteriological characteristics of peeled and deveined prawns during different stages of processing

Description of sample	T.M.A. mg. N%	T.V.N. mg. %	*a*-amino N mg. %	Non-protein N mg. %	Bacterial count/gm.
Series I					
Initial ..	2·1	16·1	117·90	532·0	$1·4\times10^{6}$
Stored in chill room for 14 hours	2·1	9·1	34·65	252·0	$8·2\times10^{6}$
After freezing ...	2·1	5·6	34·65	364·0	$1·9\times10^{5}$
Series II					
Initial ..	1·3	9·8	..	..	$2·6\times10^{5}$
Stored in chill room for 14 hours	0·7	4·9	69·31	322·0	$3·3\times10^{5}$
After washing ..	4·9	13·3	..	..	$4·3\times10^{5}$
After freezing ..	..	..	..	..	$1·0\times10^{4}$
Series III (small size)					
Initial ..	4·0	9·6	107·40	644·0	$3·7\times10^{6}$
Stored in chill room for 14 hours	2·8	9·1	38·13	588·0	$6·0\times10^{6}$

TABLE IV

Changes in the quality of frozen prawn during storage

Description of sample	Period of storage	T.M.A. mg. N%	T.V.N. mg. %	Bacterial count/gm.
Headless—fresh frozen	Initial	.	..	$3{\cdot}8\times10^4$
	1 week	0·70	14·7	$4{\cdot}0\times10^4$
	6 weeks	2·10	11·9	$2{\cdot}0\times10^4$
	13 ,,	0·70	14·0	$0{\cdot}6\times10^3$
P and D—fresh frozen	Initial	..	..	$1{\cdot}0\times10^4$
	1 week	2·80	9·1	$3{\cdot}1\times10^4$
	6 weeks	2·10	9·8	$2{\cdot}0\times10^5$
	13 ,,	0·70	14·0	$1{\cdot}9\times10^4$
Cooked frozen	Initial	..	..	$1{\cdot}4\times10^4$
	1 week	nil	7·0	$1{\cdot}0\times10^4$
	6 weeks	1·4	6·3	$5{\cdot}0\times10^5$
	13 ,,	nil	5·6	$3{\cdot}2\times10^5$

species of prawn of commercial importance have been followed during spoilage at room temperature. The values obtained are presented in Table V.

TABLE V

Changes in the pH during spoilage of prawn at room temperature*

Sample	Initial	After 5 hours	After 24 hours
Metapenaeus monoceros ..	6·60	6·70	7·45
Do. ..	6·60	6·95	8·05
Parapenaeopsis styliferus ..	6·80	7·20	..
Metapenaeus dobsoni ..	6·54	6·80	7·50

* Each figure recorded is the average of 15 estimations.

DISCUSSION AND CONCLUSIONS

It may be seen from Table I that the T.M.A. content of fresh prawn varied from almost nil to about 3·0 mg. N%. The variation in the T.M.A.

content during the initial period of spoilage up to 5 hours is almost negligible. This is also true in the case of T.V.N., the change becoming significant only after 8 hours of spoilage under room temperature. The data on non-protein nitrogen is too meagre to draw any conclusions while no appreciable variation is noticed in the case of *a*-amino nitrogen content. The pH of the flesh also does not vary significantly during the initial stages of spoilage as indicated by Tables I and V. The variation in the pH within the course of 24 hours is only of the order of one unit. These clearly show that pH value cannot be considered as an index of spoilage in prawn especially during the early stages of spoilage. This is in full agreement with the findings of other workers in regard to fish and shell fish (Elliot, 1947; Kondrup, 1948; Fieger, Novak and Bailey, 1956). However Iyengar *et al.* (1960) observe that pH of the meat together with its bacterial count would be useful as an index of spoilage in ice-stored shrimp.

The data collected on the bacterial load of fresh prawns indicate that the flesh of fresh prawn is not sterile. There is also a steady increase in the total bacterial count during spoilage and as such these figures become very significant in assessing the overall quality of the prawn. Recently Velankar *et al.* (1961 *a* and *b*) have proposed the volatile acid number as a useful index to assess the spoilage of prawn both at room temperature and in ice storage.

The data presented in Tables II and III indicate that the raw material, both headless and peeled and deveined, are in a fairly advanced stage of spoilage judged from the bacterial counts. The bacterial counts are much more than that of fresh prawn examined in the laboratory. The initial load of $1 \cdot 0 \times 10^7$ observed in the case of one sample of ' headless ' prawn (Series I in Table II) is nearly equal to that observed in flesh of the same species after incipient spoilage. This very high bacterial count of the raw material is only indicative of the fact that some spoilage has taken place either at the peeling centres or during transport. It is however noteworthy that the bacterial load or the other chemical factors do not increase much when once the materials reach the factory. Washing and cleaning do not appear to have any effect in leaching out the water-soluble volatile compounds. However there is a certain amount of reduction in the bacterial count as a result of these operations. But this reduction is not so significant as has been reported by Sreenivasan (1959). The difference may be due to the fact that while the surface bacteria are leached out during the washing process the inherent bacteria will continue to multiply as the washing and cleaning operations generally take more than 30 minutes under factory conditions. In regard to T.V.N. contents there is reduction observed in the final product.

This may probably be due to the further leaching of the volatile constituents during thawing. These figures of T.V.N., therefore, are not likely to present the true picture of the quality of the frozen product.

The T.V.N., non-protein N and *a*-amino nitrogen values of the peeled and deveined samples show a decrease after being in the chill room and after freezing (Table III). This again can be explained as due to the leaching effect. In the case of peeled and deveined material the leaching of these constituents are likely to be more because of the fact that larger flesh surface is in contact with the ice and water. Similar observations have been made by Velankar and Govindan (1958) in the case of *a*-amino nitrogen in ice-stored whole prawns. Quite contrary to this the ' headless ' samples do not show any significant changes in the above constituents either after storage in chill room or after freezing.

The data presented in Table IV clearly indicate that the frozen samples do not undergo much change during frozen storage for a period of 13 weeks.

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VARIATIONS IN THE CHEMICAL COMPOSITION OF THREE FRESHWATER FISHES OF BHAVANISAGAR RESERVOIR*

By A. Sreenivasan and M. V. Natarajan

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Fat variation in marine species of fish has been studied extensively in India (Venkataraman and Chari, 1953; Vasavan *et al.*, 1960). But it is not known whether any such variations occur in freshwater fishes. Three dominant species of Bhavanisagar Reservoir were therefore chosen for this study, the fishes taken up being two cat fishes *Wallago attu* and *Macrones* (*Mystus*) *aor*, and a cyprinid, *Barbus dubius.*

Experimental

Fish caught in the gill nets in the experimental fishing units were taken up for analysis. To the extent available at least one fish per month was analysed. Methods of handling, sampling and analysis have been enumerated in an earlier paper (Natarajan and Sreenivasan, 1961). The flesh of the whole fish was taken up, minced well and a portion taken for analysis. Differences, if any, between different parts of the fish are obviated thus.

Results

Variations in fat, moisture and protein represented in Fig. 1. The data on variations for the entire period of over the two years is summarized in Table I.

	Per cent.		
	Water	Fat	Protein
Barbus dubius ..	72·56–80·45 (1·11)	0·30–7·20 (24·27)	16·76–19·26 (1·15)
Macrones aor ..	76·17–84·83 (1·11)	0·21–4·55 (21·67)	14·88–19·04 (1·28)
Wallago attu ..	77·71–81·87 (1·05)	0·50–1·97 (3·94)	15·03–17·97 (1·20)

(Figures in paranthesis are "Variation Factor" of Thurston *et al.*, 1959).

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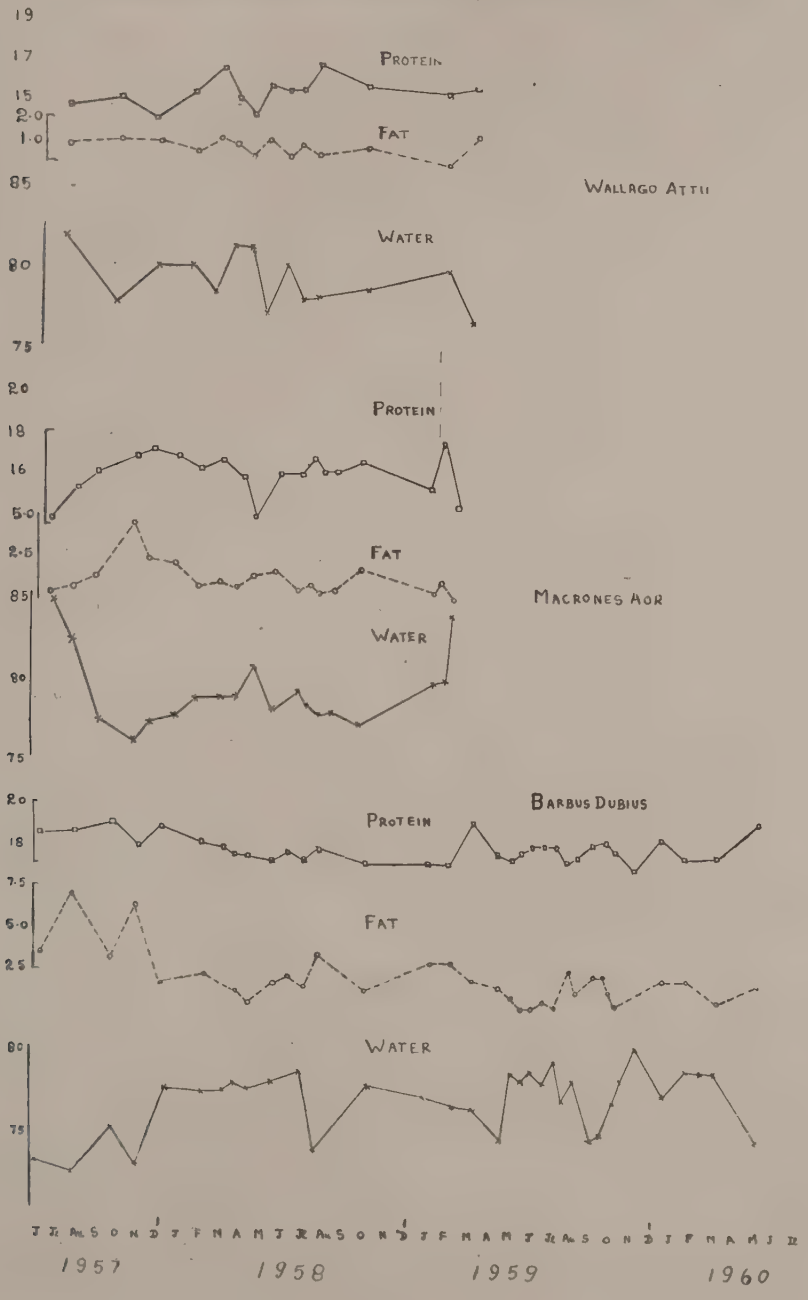
19
17
PROTEIN
15
2·0
1·0
FAT
85
WALLAGO ATTU
WATER
80
75
20
PROTEIN
18
16
5·0
2·5
FAT
85
MACRONES AOR
WATER
80
75
20
BARBUS DUBIUS
PROTEIN
18
7·5
5·0
FAT
2·5
80
WATER
75
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J
1957
1958
1959
1960

FIG. 1

Discussion

From the summarized table (Table I) it is evident that very limited variation in the proximate composition occurs in *Barbus dubius*. The maximum fat content of this fish over a period of three years is only 7·20%. It is much less in *Macrones aor* and the least in *Wallago attu*. Variations in water and protein are also very narrow. From Fig. 1, it is seen that fat and moisture are inversely correlated, particularly in *Barbus dubius*. In the case of the two cat-fishes, however it is the protein that correlates inversely with moisture. Though a striking seasonal variation is not noticed with regard to even fat content, higher fat content within a year generally occurs between July and October in *Barbus dubius*. Since this fish breeds during North-East monsoon and makes a short local migration, it appears that this limited build up of fat is to provide the energy for the upstream migration. But this cannot be compared with the long-range migration of Salmon, which stores a high fat content (Idler and Bitners, 1958). The fat content is not correlated with size of fish or with the " coefficient of condition". The highest fat content in *Barbus dubius* was 7·2%, the average fat content based on three years' data is 2·04%. Similarly the average fat content of *Macrones aor* and *Wallago attu* are 1·24 and 0·94% respectively.

A comparison with the data of Thurston *et al.* (1959) on American freshwater fishes shows that the carp shows a wider range of fat in its muscle than does the cat fish (*Ameiurus melas*). Generally it appears that predatory and carnivorous fishes have a lower fat content than plankton feeding fishes. Sohn *et al.* (1961) have shown that the fat content and its variation is very great in Mackerel but low in cod, haddock and ocean perch. The data furnished by Thompson (1959) for some sea fish and Thurston *et al.* (1959) for freshwater fish supports the conclusions. Morawa (1956) showed that for the perch (*Perca fluviatilis* L.) the fat of muscle throughout the year was about 1–2%. Our results presented here show that fat content and its variation was insignificant in the carnivorous fish *Macrones aor* and the predator *Wallago attu*. But in *Barbus dubius* which feeds on insects, oligochaets and plankton (Ranganathan and Radha, personal communication) the fat content is higher. In *Labeo fimbriatus* which is more of a plankton feeder, a still higher fat content of 10·81% was reached (Sreenivasan and Sounderaraj, unpublished). High fat content in fishes is correlated with pelagic migratory plankton feeding fishes (Sohn *et al.*, 1961; Venkataraman and Chari, 1953; Thompson, 1959). In Bhavanisagar Reservoir, the fishes are local migratory which explains the dispensability of fat storage in them.

Fat content of freshwater fishes seems also to be influenced by the ecological conditions (Morawa, 1960).

Unlike in the case of *Labeo fimbriatus* in which during particular months the protein content is low (Sreenivasan and Sounderaraj, unpublished), the fishes studied herein have a higher average protein content, *e.g.*, *Barbus dubius*, 17·93%, *Macrones aor*, 17·3% and *Wallago attu* 16·65%, and the variation is very little. Hence the nutrtive value (from the point of view of protein availability) is fairly high throughout the year.

Summary

The variations in fat, moisture, protein and ash of three freshwater fluviatile species of fish have been studied. Except in the case of *Barbus dubius* the fat was very low and variation in its content also limited. The protein content of all the three species was fairly high throughout the year. Very slight variation was noticed in ash.

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ON SOME ASPECTS OF QUALITY OF COOKED FROZEN PRAWNS

By V. Krishna Pillai and A. Lekshmy

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Introduction

Prawns of more than 100 counts to the pound are generally precooked before freezing and packing. As in the case of all precooked frozen foods expert care is required to maintain high quality in cooked frozen prawns also. A total bacterial count of 100,000–200,000 per gram muscle is suggested as an arbitrary limit for an acceptable quality of cooked frozen prawn in many countries (Goresline, 1959). The freshness of raw material, no doubt, decides to a large extent the quality of the final pack. A raw material of questionable freshness may yield a product having off odours and flavour.

In the preparation of cooked frozen prawn the normal practice is to dip wire baskets containing 30 pound load of peeled prawn in boiling brine of 30–50 salinometer for periods ranging from $1\frac{1}{2}$ to 3 minutes. The material in the baskets is kept stirred to facilitate even cooking. The basket is taken out, allowed to drain for a few seconds and spread on wire mesh table to cool. In certain factories the cooked material is dipped in chilled water containing small quantities of salt for periods not exceeding one minute. In both cases the material is packed for freezing after it has cooled and after the surface moisture has drained off.

Whatever be the original bacterial load of the material the product is partially sterilized during the cooking process. Under this circumstance if the cooked prawn is packed and frozen in a hygienic manner the final product should show only a very low bacterial count. But in practice such ideal conditions are not achieved and as such the finished products invariably record higher bacterial counts. In working out control measures for the maintenance of high quality the various factors responsible for contamination of the cooked prawn will have to be taken into consideration.

The experiments described below were carried out to study the various aspects of this problem. In this connection the authors wish to place on record their thanks to the prawn freezers in Cochin for their wholehearted co-operation during the course of the work and to Miss Annamma Mathew for assistance.

Experimental

In order to understand the changes taking place in the bacterial content of cooked frozen prawn at different stages of processing several series of experiments were carried out. Bacterial counts on each batch of prawn were taken immediately (Anon, 1958) after cooking, after cooling and packing and after freezing. These studies were also designed to understand the effect of time interval between cooking and freezing on the final quality of the product. The results of a few typical experiments are given in Table I.

Table I

Bacterial load in cooked frozen prawn during different stages of processing

(Bacterial counts expressed as number of organisms per gram)

Bacterial count of material	Cooling time	Bacterial count per gram muscle		
		after cooking	before packing	after freezing
205,000	3 hours	360	116,000	326,000
487,000	2½ hours	1,000	450,000	384,000
143,000	1½ hours	270	130,000	325,000
356,500	1 hour	900	29,600	180,000

Table II gives the results of three series of trials in which the same raw material was frozen after two different intervals. These two series indicated clearly that most of the bacterial contamination of the cooked material takes place during the cooling time—the more the time interval, the greater is the rate of contamination.

The extent of external contamination of the material and the rate of multiplication of the inherent bacteria in the cooked prawn during the cooling period were to be determined clearly. Prawns immediately after cooking were incubated under sterile and non-sterile conditions at different temperatures and observations on total bacterial plate counts recorded at different intervals. A few experiments were also carried out to examine how far a contaminated surface affects the count during incubation. A few typical results are tabulated in Table III.

TABLE II

Effect of different cooling periods on bacterial count

(Bacterial counts expressed as number of organisms per gram)

Bacterial count of raw material	Trial No.	Bacterial count after cooking	Cooled for 30 min.		Cooled for 1 hour	
			after cooling	after freezing	after cooling	after freezing
147,000	1	110	32,000	25,000	100,000	940,000
	2	96	12,000	18,000	55,000	210,000
	3	Nil	8,000	38,000	64,000	100,000

TABLE III

Bacterial count of cooked prawn at different stages of incubation

(Expressed as number of organisms per gram)

	Initial	90 min.	150 min.	240 min.	300 min.
I (*a*)	1,982	73	30	..	438
(*b*)	2,267	2,128	2,100	3,291	5,976
(*c*)	2,663	2,238	2,661	4,069	4,039
II (*a*)	256	159	75	40	1,401
(*b*)	91	73	78	185	366
(*c*)	2,933	2,053	4,057	6,247	40,413
III (*a*)	453	181	163	121	2,042
(*b*)	510	654	501	525	1,213
(*c*)	12,388	1,25407	1,031,870	2,376,909	6,591,176
IV (*a*)	364	112	79	70	245
(*b*)	326	183	356	561	1,024
(*c*)	4,970	6,215	32,784	87,824	1,470,000

a—Incubated at 55° C. in sterile dish.

b—Incubated at 30° C. in sterile dish.

c—Incubated at room temperature in containers which held the raw material and exposed to air.

The rate of cooling of cooked prawn under ordinary factory atmospheric conditions and under the influence of a current of air from a fan was studied in detail. The averages of a number of temperature recordings on different batches of prawns are plotted into graph (Fig. 2). For quick cooling of the cooked material a box-type cooler was used (Fig. 1). A blast of air from a fan at one end of the cooling box takes away the moisture and the heat from the material which are arranged in trays in the box. In experimental trials the cooling time is reduced to about 12 minutes and packing was commenced immediately. The resultant products showed only a very low bacterial count as is evidenced by the results given in Table IV. External con-

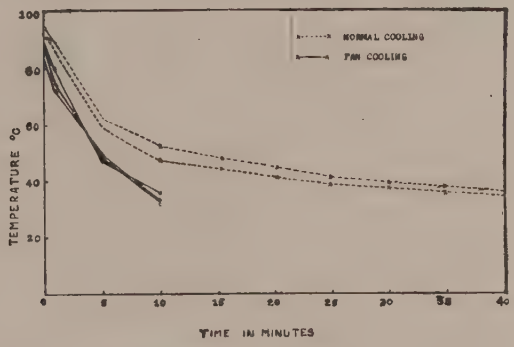

FIG. 1. Graph showing rate of cooling of cooked prawn.

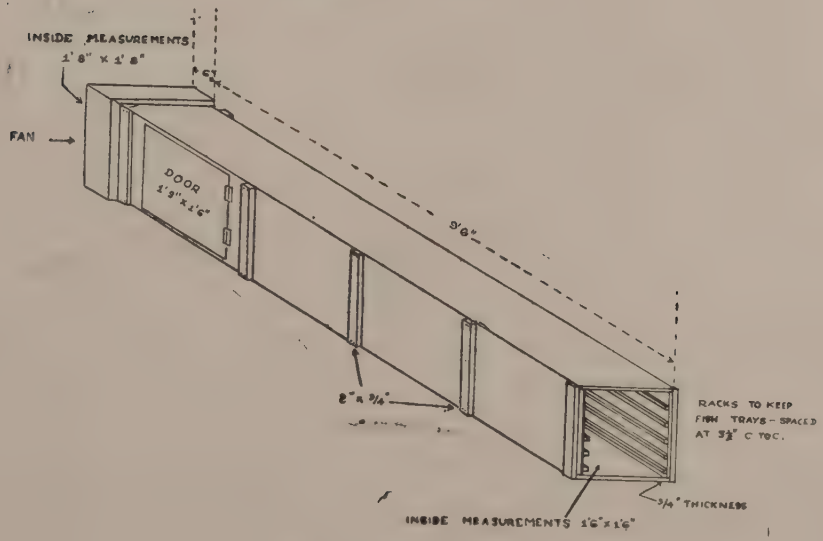

FIG. 2. Cooling Tunnel.

tamination was kept at minimum in these trials by cleaning the utensils with bleaching-powder solution containing 50 p.p.m. available chlorine prior to the experiments.

TABLE IV

Changes in the bacterial counts of cooked prawn under fan cooling

(Bacterial counts expressed as number of organisms per gram)

Immediately after cooking	After cooling for 12 min.	After freezing
1,200	2,100	below 1,000
580	1,700	below 1,000
500	7,000	4,200

In the case of chilling process of cooling where the basket containing the hot blanched material is immersed in a tub of water cooled to around 2° C. with ice trial freezing under various experimental conditions was carried out. These showed that there is another source of contamination, *viz.*, that due to bacteria carried by the ice used in chilling the water. The results of three series of experiments are given in Table V.

In another series of freezing trials water cooled in the chill storage to around 2° C. without adding ice was used both for the purpose of initial chilling of the cooked prawn and for the final glazing. The results are given in Table VI. It may be noted that these freezing trials were carried out under semi-commercial level and after allowing the usual time interval of 1–1½ hours between cooling and packing.

DISCUSSION OF RESULTS AND RECOMMENDATIONS

The results given in Table I indicate that in the air cooling technique of the preparation of cooked frozen prawn the major factor involved is the contamination of the material during the stages subsequent to cooking. The data further show that the bacterial count is brought down to below 1,000 organisms per gram as a result of cooking. But this figure is found to have increased to 400,000/gram and above during the course of about 2½ hours of cooling in the factory atmosphere. Incubation studies recorded in

TABLE V

Changes in the bacterial count of cooked prawn under chilled water cooling

(Bacterial counts expressed as number of organisms per gram)

	Series I	Series II	Series III
Raw material	74,000,000	700,000	1,000,000
After cooking	500	150	300
After cooling	53,000	4,200	6,000
After packing	38,000	5,700	20,000
After glazing with tap-water in ordinary trays	33,000	31,000	32,000
After glazing with tap-water in ordinary trays after freezing	25,000	18,000	60,000
After glazing with ice-water in ordinary trays	29,000	15,000	40,000
After glazing with ice-water in ordinary trays after freezing	40,000	26,000	38,000
After glazing with tap-water in trays washed with bleaching powder	30,000	43,000	48,000
After glazing with tap-water in trays washed with bleaching-powder after freezing	30,000	14,500	47,000
After glazing with ice-water in trays washed with bleaching-powder solution	42,000	10,600	50,000
After glazing with ice-water in trays washed with bleaching-powder solution after freezing	7,000	34,000	61,000

TABLE VI

Effect of using water cooled in the chill room on the bacterial counts of cooked prawn

(Figures expressed as number of organisms per gram)

	Series I	Series II	Series III
Raw material	2,800,000	..	..
After cooling	5,000	3,400	3,600
After packing	25,000	44,000	15,000
After glazing	47,000	60,000	16,500
After freezing	32,000	42,000	22,000
After reglazing	42,000	40,000	23,000
After keeping in frozen storage for 3 days	29,000	27,000	19,000

Table III however show that the actual multiplication of the inherent bacteria during the same period is not very significant. At 30° C. the increase in the bacterial count in 5 hours is less than four times the initial count in almost all cases reported. It may, however, be observed that when the same material was incubated at 30° C. in polluted containers the increase in the count was enormous. In this case contamination takes place both from the container and from the atmosphere. Incidentally incubation of the material at 55° C. in sterile containers result in a progressive reduction of the bacterial count in the initial stages of incubation. This may probably mean that the bacteria slowly die at the high temperature of 55° C. which is suitable only for the growth of thermophiles.

In the light of the above finding the high bacterial count shown by samples of cooked prawns after the cooling period (Table I) cannot be attributed to the multiplication of the residual bacteria. The only other possible source is external contamination from the utensils, from the hands of the workers and from the factory atmosphere. Such contamination is also found to be almost proportional to the time of exposure of the material to the atmosphere as is revealed by the data presented in the same table. This conclusion is further borne out by the results obtained when the same raw material was frozen after exposing for two different time intervals (Table II). The increase in the bacterial count of the final frozen product as a result of an increase of 30 minutes in the cooling time is of the order of anything between 3 and 40 times. Table IV gives further results of freezing trials where the cooling time was reduced to a minimum. These freezing trials were carried out with very little of external contamination. All the utensils coming into contact with the material were cleaned well in running water and properly disinfected using bleaching-powder solution. All the three batches of freezing trials carried out under these conditions gave very low bacterial counts in the final products.

Figure 1 indicates that in ordinary air cooling although there is a sudden drop in the temperature of the material from around 90° C. to 55–60° C. during the first five minutes subsequent cooling is very slow. The material remains in the temperature range 55–30° C. for over 30–40 minutes. Most of the thermophiles and mesophiles added on to the material from the environment during exposure find favourable conditions for rapid growth during this stage. The purpose of introducing the box cooler is to reduce the chances of such contamination and consequent growth of the organisms by reducing the cooling period to the absolute minimum. It may be seen

that under fan cooling the material remains in the above critical range of temperature for only less than 7 minutes.

The experiments conducted with chilled prawn samples (Table V) reveal many interesting points. The bacterial counts of the almost sterile cooked products increase considerably during the chilling process which lasts only for a period of less than one minute. Since the period is very short the increase in the bacterial count must have been due to contamination from some other source. Random examination of the water and ice used for chilling the material showed that the ice used in the experiments was not prepared from chlorinated water and that it contained a very heavy load of bacteria—of the order of 200,000 organisms per gram. The cooked material obviously gets a surface coating of bacteria during the chilling process. This contamination is carried right through the process of packing during which a certain amount of additional contamination takes place from the tables, containers, etc. It is further seen that there is no substantial reduction in the bacterial count of the finished products in these experiments as could naturally be expected. This is probably due to the further contamination of the material before freezing by the glazing water which also is cooled by contaminated ice. This also probably explains the comparatively high counts shown by samples glazed by ice-water.

Table VI gives results of experiments where most of the above defects are minimised to the maximum possible extent under factory conditions. Instead of using ice-cooled water for chilling the water was precooled in the chill storage to a temperature of about 2° C. in clean containers. The vessels and other utensils were washed and disinfected with bleaching-powder solution before starting the experiments. Other details like preparation of the material, grading and packing were similar to those followed in the factories. Even a cooling time of 1–1½ hours was allowed in the case of these trials to study the effects of the improvements under practical commercial conditions. The results obtained with these semi-commercial samples are very encouraging, the total bacterial counts keeping well below 50,000 organisms per gram in all the samples.

Based on the above results the following may be recommended for maintaining quality in cooked-frozen prawns:

1. The raw material used shall be fresh.

2. The material shall be cooked in boiling brine for just enough time, *i.e.*, between 1½ to 3 minutes, without being over-cooked.

3. If chilled by dipping in cold water, the water used shall be free from bacterial contamination and shall be pre-cooled in a chill storage. If, however, ice is used to cool the water the ice shall be prepared from chlorinated water.

4. In the case of air cooling where the temperature of the material is brought down to that of the atmosphere the cooling period shall be kept at a minimum and the material shall be loaded into the freezing equipment as soon as possible.

5. Tables, trays and other utensils that come in contact with the material shall be cleaned well and disinfected.

6. Only clean, pre-cooled water shall be used for glazing both before and after freezing.

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GOVERNMENT OF INDIA
CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, MARINE FISHERIES P.O., MANDAPAM CAMP, SOUTH INDIA

ANNUAL REPORT OF THE DIRECTOR FOR THE YEAR ENDING 31st MARCH 1961

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I. Administrative and General

Steady progress was maintained during the year 1960–61 in the implementation of the various programmes of work under the normal and Second Five-Year Plan schemes both at the Headquarters Station and the different subordinate establishments covering the entire coast-line of India. Systematic studies and the collection of data, on the economically important fishes, were continued at all the important fishery centres. Active efforts were continued to be made for the collection of scientific data and material from the Minicoy-Laccadive area and these studies have yielded very interesting results. The Centre at Minicoy is being strengthened by the appointment of an Assistant Research Officer there. A preliminary study was made of the fishery resources of the Andaman and Nicobar area with a view to exploring the possibility of setting up a research unit there under the expanded activities of the Research Institute during the Third Five-Year Plan period. A new research centre at Cannanore was opened with adequate complement of staff to intensify the studies on mackerel and sardines and also the general ecological problems there.

The total landings of marine fish during 1960 were estimated at 878,242 metric tons which was the highest figure recorded since 1950 and was nearly three lakhs metric tons higher than the figure for 1959. The fish landings in all the States registered increase over those of 1959, but the most outstanding increases were recorded in Kerala, Mysore, Maharashtra and Gujerat, while the landings by mechanized vessels also registered some increase. Volume VII, No. 1 of the *Indian Journal of Fisheries* was published during the year.

The Budget allotment for the year under the heads "recurring" and "non-recurring" amounted to Rs. Eleven and Three lakhs respectively. Among the important items of capital works that were taken up during the year mention could be made of the renovation and extensive repairs to the laboratory blocks at the Research Institute at its Headquarters Station. This work is over in respect of two blocks and the remaining works are also expected to be completed within the next few months.

A supply of underwater diving equipment required in connexion with our projected studies on exploratory survey of the pearl and chank beds off Tuticorin has recently been received from the United Kingdom. Two Pablo Boats intended for the Karwar Research Unit and Vizhingam Research Centre have been received through the Directorate-General of Supplies and Disposals.

The library of the Research Institute was considerably augmented with the acquisition of some rare and new books and publications, maps, etc., and by increasing the number of periodicals subscribed for. Considerable additions have been made also by exchange of publications for the *Indian Journal of Fisheries* but requests for exchange facilities with our Journal are constantly on the increase and in view of the limited quota prescribed for exchange and free distribution of the Journal, a number of requests could not be fulfilled. A list of research publications from the Institute during the year is given at the end of the Report.

The following appointments of Assistant Research Officers were made during the year.

Shri S. Mahadevan, Shri G. Raju (he, however, relinquished the post subsequently), Shri P. T. Thomas, Shri M. J. Pradhan, Dr. V. S. Durve, Shri M. R. Patil.

Shri M. Krishna Menon, Research Officer (for Prawns), who was due to retire from service on 13–1–1961 on attaining superannuation, was granted extension of service for one year.

Sanction has been accorded by Government for the conversion of 68 temporary Class I, II, III and IV posts in the Research Institute into permanent ones with effect from 17–12–1960 and action for the confirmation of staff against these posts has been taken.

Dr. (Mrs.) F. Thivy, Assistant Research Officer (for Marine Algology), who was re-employed in the same post for one year from 5–10–1959 on attaining superannuation, relinquished the post on completion of the re-employment period. Dr. S. V. Job, Officiating Assistant Research Officer (for Physiology) in this Institute, relinquished his post on selection to the post of Reader in Zoology under the University of Madras. Dr. R. Viswanathan and Shri T. Joseph who are holding permanent appointments in this Institute were relieved of their duties here to take up appointments under the Atomic Energy Commission, Bombay, and the Central Inland Fisheries Research Institute, Barrackpore, respectively. A number of temporary staff members were declared quasi-permanent during the year.

Dr. S. Jones and Dr. R. Raghu Prasad, Research Officer, participated the Standing Fisheries Research Committee meetings at Puri in December 1960, and later in February 1961. Dr. S. Jones participated at the meeting on deep-sea fishing operations convened by the Ministry at Cochin. He also held

discussions then with Dr. Snyder, the Co-ordinator of Indian Oceanographic Expedition, regarding oceanographic work and other related matters.

Dr. S. V. Bapat and Shri M. J. George, Assistant Research Officers, and Dr. R. Prasanna Varma, Research Assistant, have been deputed for advanced training in Canada, U.S.A., and Japan respectively during the year.

The number of visitors to the Institute showed a substantial increase during the year. The following were the more important distinguished visitors to the Institute:

Dr. S. A. Beatty, Food and Agricultural Organisation, Processing Expert.

Dr. David C. Rife, Deputy Scientific Attache, U.S. Embassy, New Delhi.

Miss M. Bryant, UNESCO Fellow from Liberia.

Miss Gillespie, WHO Nursing Adviser.

Dr. David D. Keck, National Science Foundation, Washington.

Mr. Raphael S. Truc and Mr. N. M. Marajas, Philippine Scholars.

Shri Bishnuram Medhi, Governor of Madras State.

Shri P. Kakkan, Minister for Public Works, Madras State.

Shri K. R. Damle, Secretary to the Government of India, Ministry of Food and Agriculture.

Dr. A. T. Sen, Member, Union Public Service Commission.

Shri B. K. Kapoor, High Commissioner for India in Ceylon.

Shri H. K. Ghazi, Director of Fisheries, Madras State.

Shri Y. Krishnan, Accountant-General, Madras.

Shri S. Sounderarajan, Deputy Accountant-General, Madras.

Dr. A. N. Kappanna, Director, Central Salt Research Institute, Bhavnagar.

Shri P. I. Chacko, Deputy Director of Fisheries, Madras.

Dr. A. P. Kapur, Deputy Director, Zoological Survey of India.

Dr. S. Z. Qasim, Reader in Zoology, Aligarh University.

Shri K. T. K. Thangamani, Member, Parliament.

Col. B. M. Chakravarthi, Director, Electronics Research and Development Organization, Bangalore.

Col. K. K. Mehta, Chief Inspector (Electronics), Ministry of Defence, Bangalore.

Prof. Von Brandt, Director, Institute of Nets and Materials, Hamburg, Mr. Hareide Sr., Member of Norwegian Parliament and Member of Norwegian India Foundation, Mr. Idar Letnes, Marketing Expert of Indo-Norwegian Project, Shri A. I. George, Director of Fisheries, Kerala, and Shri P. M. Thomas, Deputy Director, Ministry of Food and Agriculture and Deputy Storage Adviser, Central Warehousing Corporation, visited the Kozhikode Substation of this Institute while Srimati Lourdhammal Simon, Minister for Local Administration and Fisheries, Madras, and Shri Kishan Chand, Joint Secretary, Ministry of Food and Agriculture (Department of Agriculture), New Delhi, visited the Ernakulam Substation and the Madras Unit respectively.

The Research Scholars working under the Ministry of Scientific Research and Cultural Affairs and the Council of Scientific and Industrial Research continued to make satisfactory progress with their researches. The Central Marine Fisheries Research Institute has recently been recognized as a centre for post-graduate research work leading to the Ph.D. Degree of the Banaras Hindu University in respect of candidates possessing the M.Sc. degrees of that University. The Pool Officer of the Council of Scientific and Industrial Research (Dr. E. G. Silas) attached to this Institute is making satisfactory progress with his research work.

The activities of the Institute were filmed by the Films Division of the Ministry of Information and Broadcasting. The Institute continued to extend help and facilities to a number of student parties from Universities, colleges and schools, who wanted to acquaint themselves with the research work carried out here. Facilities for study were also extended to a number of individual scientific workers. The M.Sc. students of Zoology of the Madras University were given training in Marine Biology in our laboratories by special arrangements and lectures were given by our staff at Headquarters and subordinate establishments to the All-India Fishery Trainees from the Central Inland Fisheries Research Institute, Barrackpore. Students, from a large number of educational institutions, visited the Institute.

II. Fishery Survey

The analysis of data collected in 1960 was completed during the year under review and the total landings of marine fish during 1960 were estimated at 8,78,242 m. tons as compared to 5,84,193 m. tons in 1959, showing an increase of about three lakhs metric tons. It may be noted that the landings of marine fish in 1960 had been the highest since 1950. The Statewar break up of the total landings for 1960 and 1959 are given in Table I.

TABLE I

State	Fish landings in metric tons	
	1960	1959
1. West Bengal and Orissa ..	5,532	3,962
2. Andhra ..	56,720	29,464
3. Madras ..	1,07,810	1,03,497
4. Kerala ..	3,44,605	1,91,375
5. Mysore .	1,00,557	52,825
6. Maharashtra ..	1,27,172	1,98,192
7. Gujerat ..	1,27,982	
8. South Andaman .	129	123
9. Laccadive Islands ..	509	..
10. Trawler catches ..	7,226	4,755
TOTAL ..	8,78,242	5,84,193

It will be seen from Table I that landings in all the maritime States of India showed improvement as compared to those of 1959. The most significant increase in the catches had been in Andhra, Kerala, Mysore and Maharashtra and Gujerat. The landings from trawlers also registered a significant increase.

The landings in West Bengal and Orissa increased by about 1,500 metric tons as compared to those of last year. This was mainly contributed by increased landings of other sardines, sciaenids, penaeid prawns, *Chirocentrus*, elasmobranchs, ribbonfish, seer fish and *Anchoviella*.

In Andhra landings were nearly double. This was due to unusually heavy landings obtained in North Andhra during the first quarter of 1960. The landings of clupeids in the State showed an increase of about 10,000 metric tons. Significant increase was also noticed in the landings of elasmobranchs, mackerel, silverbellies, sciaenids, pomfrets, carangids, red mullets, perches, cat-fish, *Lactarius*, polynemids, soles and eels.

In Madras State landings of ribbonfish, *Lactarius*, perches and cat-fishes showed some decline. But this decline was more than compensated by

increased landings of flying fish, carangids, elasmobranchs, clupeids, *Leiognathus*, crustaceans and soles.

The landings in Kerala were increased by 1,53,230 metric tons. This was due to successful fisheries of oil sardine and mackerel. The increase in the landings of sardine and mackerel came to the tune of 1,35,000 metric tons. It had been observed that the heavy landings of oil sardine created a glut condition thereby discouraging fishermen from fishing. If the fishermen had fished all along, the landings in Kerala would have been much higher than the reported figure. Apart from oil sardine and mackerel, there was a significant increase in respect of landings of *Caranx*, cat-fish, *Anchoviella*, *Lactarius*, soles, tunnies, and *Sphyraena*. Some decline in the landings of ribbonfish, other sardines, prawns, *Thrissocles*, pomfrets, *Chorinemus*, and *Chirocentrus* was, however, noticed during the year in this State.

Increased landings in Mysore were mainly due to higher landings of mackerel. In fact the mackerel landings in the State was the highest recorded since 1950. An appreciable increase in respect of landings of *Anchoviella*, carangids, seer fish, *Lactarius*, pomfrets, soles and tunnies was also noticed. A significant fall was also recorded in the landings of cat-fish, prawns and *Thrissocles*.

The landings in Maharashtra and Gujerat showed increase by about 57,000 metric tons. The landings of sardines, other clupeids, Polynemids and *Chirocentrus* showed a decline. But this decline was more than compensated by increased landings of Bombay duck, *Hilsa*, prawns, elasmobranchs, pomfrets and cat-fish.

Table II shows the overall composition of the total marine fish landings in India during 1960. For comparison, the corresponding figures of 1959 are also given.

It will be seen from Table II that an increase of about 1,91,000 metric tons was accounted for by increased landings of oil sardine, and mackerel. *Harpodon nehereus*, carangids, elasmobranchs, *Anchoviella*, *Hilsa*, flying fish, tunnies and *Bregmaceros* accounted for an increase of nearly 107,000 metric tons. A further increase of about 27,000 metric tons was due to small increases in the landings of cat-fish, sciaenids, pomfrets, soles, silver bellies, prawns, seer fish, red mullets and *Sphyraena*.

As against these, a decline of about 25,000 metric tons resulted from decreased landings of ribbonfish, other sardines and polynemids.

TABLE II

Composition of marine fish landings

Name of fish	Quantity landed in metric tons	
	1960	1959
1. Elasmobranchs ..	35,561	23,446
2. Eels ..	6,140	6,076
3. Cat-fish ..	25,041	20,272
4. *Chirocentrus* ..	5,320	5,428
5. (*a*) Oil sardine ..	1,89,016	69,234
(*b*) Other sardines ..	32,003	41,167
(*c*) *Hilsa ilisha*	3,345	844
(*d*) Other *Hilsa* ..	8,443	3,046
(*e*) *Anchoviella* ..	35,885	24,477
(*f*) *Thrissocles* ..	7,522	8,108
(*g*) Other clupeids ..	20,274	21,211
6. (*a*) *Harpodon nehereus* ..	1,08,564	57,210
(*b*) *Saurida* and *Saurus* ..	482	597
7. *Hemirhamphus* and *Belone* ..	213	383
8. Flying fish ..	6,470	1,668
9. Perches ..	9,804	9,389
10. Red mullets ..	2,568	1,526
11. Polynemids ..	6,649	7,666
12. Sciaenids ..	24,947	20,442
13. Ribbonfish ..	17,467	31,830
14. (*a*) *Caranx* ..	21,583	9,773
(*b*) *Chorinemus* ..	4,212	2,658
(*c*) *Coryphaena* and *Elacate* ..	654	471
(*d*) *Trachynotus* ..	9	2
15. (*a*) *Leiognathus* ..	15,760	13,200
(*b*) *Gazza* ..	634	293
16. *Lactarius* ..	14,502	13,842
17. Pomfrets ..	21,850	17,389
18. Mackerel ..	1,33,655	62,198
19. Seer fish ..	8,650	6,590
20. Tunnies ..	5,615	2,866
21. *Sphyraena* ..	1,985	972
22. *Mugil* ..	895	245
23. *Bregmaceros* ..	6,096	3,821
24. Soles ..	14,103	10,360
25. (*a*) Penaeid prawns ..	31,759	27,632
(*b*) Non-penaeid prawns ..	36,271	37,805
(*c*) Other crustaceans ..	2,570	2,092
26. Cephalopods ..	462	348
27. Miscellaneous ..	11,263	17,616
TOTAL ..	8,78,242	5,84,193

The higher landings of oil sardine were due to its increased landings in Kerala. While the oil sardine fishery in 1959–60 was a dismal failure, it was very good in 1960–61 season. The oil sardine catch in 1957, which was the highest since 1950, was higher than this year's catch by only 2,453 metric tons. Actually the catch of oil sardine in 1960 could have been considerably greater, but because of glut conditions fishermen did not go for fishing on many occasions at many places. The amount of effort put in in 1960 was about only 64% of that of 1959. The mackerel fishery on its turn also was highly successful during this year. The total catch of mackerel exceeded even that of 1958 and in fact was the highest since 1950. Out of the total mackerel landings of 133·655 metric tons, 81,882 metric tons were landed in Mysore. The improved landings of *Harpodon nehereus* were due to enhanced yields in Gujerat which account for 72% of the total Bombay duck landings. It was significant that while exceptionally good catches of Bombay duck were landed in Jaffrabad area in Gujerat, the Bombay duck fishery in Maharashtra was a failure during 1960. In fact the catch of Bombay duck in Jaffrabad area was so heavy that there was a glut which restricted normal amount of fishing. Increased landings of carangids and seer fish were due to the increase in their catches in all the maritime States. Barring Mysore, elasmobranchs landings showed improvement in all the States. The augmentation of the landings of *Anchoviella* was mainly due to its heavier landings in Kerala, Andhra and Madras. Good fishery of *Hilsa* in Gujerat increased the total yields of the fish. The augmentation of the total landings of flying fish was entirely due to its heavier landings in Madras where the flying fish fishery is showing a steady improvement for the last three years. The higher landings of tunnies were mainly due to increased landings of the fish in Kerala. The significant increase in respect of landings of *Bregmaceros* and *Mugil* in Maharashtra enhanced the total catch of these fishes. Increased landings in Kerala, Maharashtra and Gujerat, Andhra and West Bengal and Orissa resulted in the overall improvement in the landings of cat-fish. The improvement in the landings of sciaenids was mainly due to increased landings of the fish in Andhra and Kerala. The total landings of pomfrets registered increase because of their heavier landings in Gujerat and Andhra. While the improvement in the landings of soles was due to their increased landings in Kerala, that of silver bellies was on account of their higher landings in Andhra. The higher landings of prawns were due to their enhanced yields in Maharashtra and Gujerat. Total landings of red mullets registered increase because of their heavier landings in Andhra. The landings of *Sphyraena* showed improvement in all the maritime States except West Bengal and Orissa.

The decline in respect of landings of ribbonfish was due to its reduced landings in Madras and Kerala. The fall in the landings of other sardines and polynemids was similarly due to their decreased landings in Kerala and Maharashtra.

Table III shows the seasonal variation in the catch landed in the different maritime States of India. These do not include the catch landed at Laccadives and Andaman and those landed by trawlers.

TABLE III

Seasonal variations in catch

(Figures in Metric Tons)

States	Period				Total
	I Quarter	II Quarter	III Quarter	IV Quarter	
West Bengal and Orissa ..	1,567	411	405	3,149	5,532
Andhra ..	22,062	12,276	8,467	13,915	56,720
Madras ..	22,078	29,873	33,525	22,334	107,810
Kerala ..	33,109	22,201	97,612	191,683	344,605
Mysore ..	7,246	793	4,605	87,913	100,557
Maharashtra ...	28,512	15,866	12,870	69,924	127,172
Gujerat ..	16,295	16,548	6,288	88,851	127,982
TOTAL ..	130,869	97,968	163,772	477,769	870,378
Per cent. ..	15·04	11·25	18·82	54·89	

From Table III it will be seen that nearly 55% of the landings were made during the last quarter of the year, which is the most productive part of the year. In fact, in all the States of West Coast and also in West Bengal and Orissa, the bulk of the landings was made in the 4th quarter. The increased landings in Kerala and Mysore during the last quarter were primarily due to incursion of mackerel and oil sardine in the inshore fishing grounds of these States. The incursion of Bombay duck, pomfrets and *Bregmaceros* in the fishing grounds was the main reason for more landings

in the last quarter in Maharashtra and Gujerat States. In Andhra, the highest landings were obtained during the first quarter when good catches consisting mainly of clupeids were obtained in N. Andhra. In Madras, there were not much seasonal variations in the landings.

Catch per unit of effort.—Table IV shows the total effort in man-hours expended in each State and also the catch in Kilogramme per man hour. The corresponding figures for 1959 are also shown for comparison.

TABLE IV

Total effort in man-hours and catch in kilogramme per man-hour

States	Effort in 1,000 man-hours		Catch in kg. per man-hour	
	1960	1959	1960	1959
1. West Bengal and Orissa ..	7,182	4,787	0·77	0·83
2. Andhra ..	48,548	47,436	1·17	0·62
3. Madras ..	66,849	69,166	1·61	1·50
4. Kerala ..	39,972	63,328	8·62	3·02
5. Mysore ..	9,879	10,271	10·18	5·14
6. Maharashtra ..	23,228	52,391	5·47	3·78
7. Gujerat ..	20,615		6·21	
8. All India Total ..	2,16,273	2,47,379	4·02	2·34

Table IV shows that the total effort expended during 1960 was less than that in 1959. The catch per unit of effort registered improvement over the last year's. The most significant decline in the amount of effort put in took place in Kerala, Maharashtra and Gujerat. In Kerala the oil sardine and mackerel fisheries were so successful that a glut condition prevailed. Fishermen did not go for fishing on many occasions, even though shoals were sighted. If the fishermen of Kerala had put in effort as in other years, the total landings in the State could have been considerably higher. In Jaffrabad area of Gujerat, the Bombay duck fishery was highly successful

and this again created glut condition in the area thereby curtailing the fishing effort normally put in other years. The amount of fishing effort in Maharashtra was lower probably because of lesser availability of fish in the area during the year.

III. Fishery Biology

A. Inshore Fisheries Investigations

1. *The Oil Sardine and Other Clupeids*

(*a*) *At Karwar*

Sardinella longiceps (Oil sardine).—The fishery started in late October and ended abruptly by the close of November, except for stray catches in December. The total landings at Karwar were estimated at 95·26 kg. as against 1,14,789 kg. for the previous year. The whole catch was accounted for by the *rampan* nets. The size range recorded for the season was 142–205 mm. The dominant size in the commercial catches of October was 165 mm. while in November, besides the 165 mm. group, there was a minor mode at 185 mm. in the length-frequency analysis. The females formed 51·8% of the samples analysed. The specimens examined during the season October to November were in maturity stages VII and II. The minimum and maximum sizes of the intra-ovarian eggs were 0·085 and 0·102 mm. respectively. Food consisted mainly of phytoplankton. *Chaetoceros* sp., *Thalassiothrix frauenfeldii* and *Coscinodiscus jonesianus* were present in the guts. Species of *Ceratium* were also found. Among copepods, *Oithona* sp. and *Acrocalanus longicornis* were the important items. Copepod nauplii were present in smaller numbers.

Sardinella fimbriata.—The 1959–60 "Pedi" season continued up to August 1960, and the current season (1960–61) commenced at Karwar in September. The catches recorded were poor compared to those in the previous years. Twenty-seven samples totalling 2,440 specimens were measured for length-frequency analysis. The forward movement of the mode could be traced from 90 mm. in September 1959 to 140 mm. in August 1960, indicating a probable growth of 50 mm. in 12 months. The 1960–61 season showed the abundance of the 100–19 mm. size group. Length-frequency studies revealed that the catches were supported mostly by a single age-group and that the fishery was constituted by the juveniles. The maturity stages recorded in April were I to IV, in May I and II, in August II and III, and from September to December I and II. The size range of the opaque intra-

ovarian eggs was found to be 0·340–0·476 mm. Food and feeding habits were also studied.

Sardinella albella.—The fecundity, maturation and spawning periodicity of *S. albella* were worked out during the year under review. It was observed that the number of mature eggs in the ovaries of the gravid females measuring 146–55 mm. varied roughly from 10,000 to 13,500 and that the left lobe of the ovary produces more eggs, than the right one the number being directly proportional to the size of the ovary. The ripe transparent eggs varied in diameter from 0·680 mm. to 1,020 mm. with the peak at 0·833–0·867 mm. The yolk was clear and segmented and provided with a single oil-globule (0·102–0·119 mm.). The absence of multiple modes in the ova-diameter frequency polygons indicated the existence of only one spawning season in a year for this fish; the duration of spawning may be extended over a long period.

(*b*) *At Mangalore*

Sardinella longiceps.—The oil sardine fishery in the Mangalore zone was better this year compared to last year. The fishery commenced in the second week of July at the southern centres and later extended to the northern centres. Relatively heavy landings were recorded especially in October and December. The annual catch at Ullal was about 78 metric tons as against about 55 tons last year. The first catch here was observed on 21st August. October–December was the most productive quarter, the total catch being about 28 tons in October and about 18 tons in December. The November landings were negligible. The January catch was slightly less than that of December but there was no oil sardine fishery at this village in February.

The cast net and the gill nets *mananguvala*, *chalabale*, and *idabale* were the main types of gear operated at Ullal. In October the major portion of the catch was accounted for by the castnet and in December by the *chalabale*. Both the types of nets were generally operated 1–2 miles from the shore (1–4 fathoms). In regard to the annual catch and the catch per unit effort, *chalabale* ranked first at Ullal. At other centres, shore-seines (*rampani* and *kairampani*) and boat-seines (*paithuvala* and *arakkollivala*) were the important types of nets used. The length-frequency studies showed that two age-groups were present in the fishery. Of these, the older one had been represented in the catches of last year also, while the younger one was newly recruited into the fishery this year. The latter first appeared in the catches in July. The older age-group could be recognised in the fishery up to the end of December. However, the bulk of the catches of this year was supported by the younger

age-group. The average annual male to female ratio was 0·48–0·52. Mature fish (stages IV and V) which belonged to the older age-group were recorded from April–August. A few spent (Stage VII) and recovering (Stage II) specimens were observed in September and October. Fish of the age-group newly recruited this year were below stage III in maturity.

A gross study of the stomach contents showed that the food consisted mainly of diatoms (*Fragilaria, Coscinodiscus, Biddulphia*, etc.) as in previous years.

(*c*) *At Cannanore*

Sardinella longiceps.—During the last quarter of the year under review, regular investigations on the oil sardine fishery were initiated at the Cannanore Research Centre. Mostly, oil sardine were landed by the boat-seines (*Mathikollivala*) and gill-nets were not operated exclusively for oil sardine. The 140–44 mm. size-group dominated the commercial catches, with the 145–49 mm. group coming next in importance. Studies were also carried out on the food and feeding habits of the species. The phytoplankton elements represented by species of *Biddulphia, Fragilaria, Coscinodiscus, Pleurosigma, Triceratium* and *Rhizosolenia* occurred much more than the zooplankton elements represented by tintinnids, copepods and larval bivalves. All specimens examined during the last quarter of the year under review were in maturity stages I or II. The fishery proved to be a fairly good one in the early part of the season when oil sardines were sold at very cheap rates for food and manure.

(*d*) *At Calicut*

Sardinella longiceps.—The estimated oil sardine landings reported at Calicut during the year 1960–61 amounted to 7,677·89 metric tons forming 96·48% of the total catch by all the gears operated for oil sardine as compared to 1,561·16 metric tons in 1959–60. The best catches, exceeding 1,000 metric tons per month were recorded during October and December 1960 and January 1961. Among the different quarters of the year, the period October–December 1960 alone accounted for 3,213·12 metric tons. More than 90% of the year's oil sardine catches were made during the months August 1960 to March 1961. The bulk of the oil sardine fishery this year was chiefly supported by the second year class, the abundance of which was very consistent throughout the year. Assuming that the abundance of the oil sardine in the inshore waters in a particular season is indicative of an increase in the rate of annual recruitment during that year, the success of this year's oil sardine fishery, chiefly contributed by the second year class, may be

attributed to the fairly good oil sardine fishery reported in 1958–59 season. Among the different gears operated for oil sardine, 6,767·63 metric tons were landed by *kollivala* and 807·89 metric tons by *thattumvala*. The oil sardine catches made by other gears were insignificant. *Kollivala* had landed 88·15% of the total oil sardine spending 73·64% of the total effort, whereas, *thattumvala* with 20·33% of the total effort, had caught 10·52% of the total oil sardine catches. Among the different gears, the highest catch per unit of effort of 18·28 kg. was recorded by *kollivala*. The general improvement in the oil sardine fishery had, to some extent, reflected on the overall high values for the catch per unit of effort for the different gears as compared to the figures during the previous year. Although oil sardine ranging in length from 80 to 204 mm. included the first to fourth year class individuals, the bulk of the fishery was supported by the second year class ranging in length from 130 to 150 mm. The regions fished for oil sardine extended from 3 to 14 fathoms but the heaviest concentrations of oil sardine shoals appeared to be in the 8–12 fathom region.

1201 Specimens were examined for maturity and spawning studies. In May the stages I and II were noticed in the earlier period and stage III in the last week. Stage IV was noticed in June. In July in addition to stage IV there was a notable entry of indeterminate (juvenile) stages. August witnessed mostly bigger fish, the majority of which had slightly advanced further from stage IV. A salient feature noticed this month was the occurrence of partly spent individuals, provisionally termed as stage IV *b*, which were recognized for the first time during the present investigations. Immature sardine again entered the fishery in the last week of August and appeared to continue in September (except for three days when specimens above 170 mm. were spent, mostly completely but some partially. From October onwards the fishery was mostly comprised of immature sardine, the larger sizes being in the spent-resting condition, the number in this category being small from January).

The sexes were about equal in numbers unlike in the previous year when the males were more numerous. Fecundity estimates fluctuated widely between 40,000 and 75,000. An instance of hermaphroditism was noticed in August, the left gonad having developed into an ovary and the right one abnormally into an ovotestis.

Studies on fat variations indicated that among the immature fish both the muscle and visceral fat started increasing from July, suddenly shot up in September and reached the maximum in December. Among the larger

fish only the spent sardine showed an appreciable quantity of visceral fat during September-October but that too started declining from November onwards.

270 Specimens fished mostly by *mathichala vala* and *pattenkollivala* were studied for the stomach contents and also for age and growth. They were fished at the depth range of 4–22 metres. Their size ranged from 87–187 mm. Most of the specimens were immature (in stage I).

Of the Bacillariophyceæ in the stomach contents, *Fragilaria oceanica* was predominating during most of the months. The other predominating forms were *Thalassiosira* sp., *Coscinodiscus* sp., *Thallasiothrix frauenfeldi*, *Pleurostigma* sp. and *Nitzschia* sp. Amongst the Dinophycæ *Dinophysis caudata* was very common. The same was true with copepods that represented the zooplankton.

Otoliths of one specimen measuring 143 mm. showed one ring and of one measuring 140 mm. showed two rings; no rings were noticed on the opercular bones.

(*e*) *At Ernakulam*

Sardinella longiceps.—At Kannamali the oil sardine fishery was moderate in April and poor in May. There was no sardine catch in June. In August there was a moderate fishery but this again declined in September. *Thanguvala*, *nona vala* and *chalavala* were used in the fishing.

The dominant mode in length frequency in April and May was at 145 mm. In August the modes ranged from 130–175 mm. while in September, the mode was at 140 mm. During April–May the females formed nearly 50% of the catches; in August 44% were females and 16% were indeterminates; in September the females formed 60% of the catch. The maturity stages were II and III respectively in April and May but V in August (with a few in stage IV also). After September no material was collected from Kannamali.

At Manassery there was no sardine fishery in April and May; in June small catches were obtained in *thanguvala* and *chalavala*. A moderate sardine fishery commenced towards the end of July and persisted up to end of September, *nona vala*, *chalavala* and *thanguvala* being operated. While the fishery was quite good in October, the largest sardine catch of the year was obtained in November. In December the fishery was better than in October. *Thanguvala* was operated.

The modal length in June ranged from 160–165 mm. In July fish having 110 mm. mode occurred. In August the modes ranged from 115–140 mm. The dominant mode in September was at 145 mm. During the third quarter the mode remained at 145 mm. In January, the modal lengths of sardine obtained in *thanguvala* and *chalavala* were 145 mm. and 175 mm. respectively while in February they were 145 and 180 mm. respectively. In March the *thanguvala* sardine showed 145 mm. mode.

The June samples were in stages IV–V of maturity. In July the majority of juveniles were indeterminates. In August the large sardine were in stage V. In September the juveniles were in stage I and the large ones in V and partly spent condition. The October samples were in stage I. In January the *thanguvala* sardine were in stage I and gill-net sardine in spent-recovering condition. In February also the same maturity conditions continued. In March the fish obtained in *thanguvala* were in stage I.

Scale studies were continued, the length ranges of the sardine examined during the first, second, third and last quarter being 150–180 mm., 170–190 mm., 140–190 mm. and 160–190 mm. respectively. A great majority of the sardine examined possessed distinct scale-rings. Otoliths collected are being examined.

(*f*) *At Vizhingam*

Sardinella longiceps.—The oil sardine supported a minor fishery at Vizhingam during the year under report. Altogether 19,161 kg. of the fish were estimated to have landed during the nine months from July 1960 to March 1961. The commercial landings of the species were confined to one or two days in a month. Gill nets and shore-seines were employed in the fishery. The catches were composed of juveniles with indeterminate and immature gonads.

The total length during the season ranged from 55 mm. to 200 mm. The modal lengths were 100 mm., 145 mm. and 160 mm. respectively for the second, third and fourth quarters of the year under report.

Analysis of the gut contents showed that the food consisted of planktonic organisms with phytoplankton predominating.

(*g*) *At Mandapam*

Dussumieria spp.—The Rainbow Sardines form one of the important fisheries of the Rameswaram Island as well as in the area in and around Mandapam. Investigations were taken up since the middle of July 1960

in order to study the potentialities of the fishery, the composition of the year-class fished, the species composition, and the general biology of this fish.

The samples analysed consisted of catches taken from Palk Bay as well as from the Gulf of Mannar side, the tackles used in landing them being boat-seine in the former case and shore-seine in the latter case. *Kolavalai* (Drift-gill net) catches were not included since it is selective in fishing. The fishing had been dull in the Gulf of Mannar while in Palk Bay regular landings were made from July to October. In all 964 fish were analysed in 16 samples of which 164 fish were specially studied for detailed morphometric and body proportions measurements. Statistics on the intensity of fishing and the length frequency of commercial catches were maintained for future evaluation of the fishery.

The fishery in the Gulf of Mannar side is made up of two seemingly different varieties unlike what was hitherto supposed as being homogeneous whereas Palk Bay shows only one of the above forms in the landings. The body proportions and other counts are distinctly different that it is now easy to differentiate them in the field itself without much difficulty. The determination of the exact species involved is engaging the attention.

A pattern of growth of the fish, their entrance into the fishing and disappearance therefrom seems evident from the data analysed. The fishery is supported mainly by the maturing as well as spawning individuals ranging in size from 120 to 150 mm.

2. *The Mackerel*—Rastrelliger canagurta

(*a*) *At Karwar.*—A total of 2,684·56 metric tons of mackerel had been landed at Karwar during the year, the *rampan* being the principal gear employed. The season started during early October and came to an end by the first week of January. It was noticed that as the season advanced and the size-group increased, the shoals of *Rastrelliger* showed a tendency to move further and further away from the shore. Since the season was very short, no secondary peak in production was observed as in certain previous years.

There were 75 fishing days when 178 hauls were made using 91,593 pieces of *rampan* net. The maximum catch and the maximum unit effort were recorded in November (1,303·9 metric tons and 45·21 kg. respectively). The quantity landed per *rampan* per haul varied considerably from a maximum of 99,174 kg. on 2nd December to 273 kg. on 10th November. These dates also showed the highest and the lowest figures respectively for any single day.

Studies on recruitment by a quantitative evaluation of the size-groups entering the fishery were initiated during the year. Analysis of the month-wise and seasonwise landings showed that three different stocks were fished. However, the fishery was mainly dependent on the 190–215 mm. size-group which accounted for 75·6% of the total. Small fish of the size-range 150–175 mm. contributed 8·65% while large fish of the range 230–255 mm. formed 2·2%.

Samples from different types of units on any particular day did not show any appreciable difference either in the range of size or in the mode. Only the large sizes occurred in the samples from April to August and these disappeared after mid-December. At the commencement of the season in the first week of October the smaller group (165–170 mm.) constituted the fishery. From late October to late November the dominant group was 190–195 mm. while from end of November to March a higher size-group (215 mm.) dominated.

The commercial fishery at Karwar was dependent on immature mackerel (stages I and II). There was no segregation of sexes during shoaling. The spawners were generally the large fish which did not enter the inshore waters in very large numbers. They were believed to come from a different stock. The appearance of fish in stage V during early September and the presence of spent fish in the catches of October–November would suggest that these fish had spawned during September.

The study on the relationship between the total length and standard length, and their relation to body weight was continued. Stomach contents of more than 250 mackerel were exhaustively studied by the number method. In June, July and August, stomachs analysed from Karwar *yendi* samples had a good number of diatoms. *Chætoceros* sp., *Fragilaria oceanica*, *Thalassiothrix frauenfeldi* and *Nitzschia seriata* were found abundantly. The major item of the gut-contents from *rampan* net was frequently sand. Samples from the off-shore collections (*pattabale*) had a good number of dino-flagellates and many zooplankton elements.

(*b*) *At Mangalore*.—The mackerel fishery at Ullal appeared to be better this year with a total catch of 81·6 metric tons in contrast to the year 1959–60 when the total estimated catch was only 21·6 metric tons. The season commenced in August 1960 with the highest monthly total catch of 40 metric tons. There was a declining trend from October onwards (with the exception of March 1961). About 72% of the catch of mackerel was landed by *idavale* and *pattabale* (gill-nets), these nets ranking first and second respec-

tively in catch per unit of effort. The cast net and the *kanthabale* ranked third and fourth respectively. Mackerel were not recorded this year in the *chalavala* and *kollivala.*

Mackerel of the size-range (120–194 mm.) contributed to the fishery from August to October when the small-meshed nets (cast-net and *idabale*) were used for the fishing. During April and from September to March, bigger mackerel (of size range 192–244 mm.) were caught in the *kanthabale* and *pattabale* which have a 2″ mesh. The length-frequency data indicated that the fishery was constituted by more than a single year-class.

During the quarter April–June there were more females (males 31, females 69) than males; during other months of the year the sex-ratio was fairly constant. Maturity stages III and IV were dominant in the April–June period. Stage III was recorded during the July–December period but the majority of fish during this period were in stage I. From January to March stage II was dominant.

Ova diameter measurements from a stage III ovary showed four modes in the frequency distribution.

Studies on food and feeding were also continued. Phytoplankton elements were dominant in the stomach contents from April to August (except in the case of stray specimens from the Netravati estuary). From the second half of August to March, zooplankton elements (*Evadne*, *Penilia* and copepods) were dominant.

(*c*) *At Cannanore.*—The mackerel fishery was good at Cannanore during the year with estimated total landings of 208 metric tons, 151·43 metric tons and 322·79 metric tons respectively during the second, third and last quarters. The highest level of abundance of the mackerel in inshore waters during the year was noticed during the months of December and January when more than 60% of the catch was landed. The nets used were the boat-seines and gill-nets the former contributing the bulk of the catches.

The fishery was mainly supported by the medium-sized and juvenile fish and to some extent by adults. Investigations at this centre were initiated only towards the end of the first quarter. Stray specimens of juveniles measuring 110–140 mm. (with mode at 120 mm.) were noticed at the close of the quarter. During the second quarter the fishery was mainly supported by the juveniles (110–120 mm.) and medium-sized mackerel (140–190 mm.) of which the latter group was dominant. The fishery during the third and fourth quarters was mainly supported by the size-group 180–230 mm. with

the mode at 210–220 mm. Thus there was a considerable increase in the size of the mackerel that contributed to the fishery in the third and last quarters of the year.

The majority of specimens examined from commercial catches were in maturity stages I and II. No mackerel above 230 mm. in total length was recorded during the period under report. At the close of the season stray adults (below 230 mm.) were in stage III of the maturity. The two sexes were about equally represented in the commercial landings.

Volumetric and quantitative analyses of the stomach contents showed that the mackerel were feeding actively on planktonic organisms and there were two peak periods of feeding—one during September–November and the other during January–March. On the whole, the phytoplanktonic fraction dominated over the zooplanktonic fraction in the food although during certain months the latter was the predominant item in the stomach contents.

(*d*) *Calicut*.—The total landings of mackerel at Calicut (Vellayil) during the year were 1,020·98 metric tons; there were no landings in the first quarter. The main nets operated were *ailachalavala*, *ailakolilvala* and *pattenkollivala*, the respective landings of the three nets being 92·19 metric tons, 882·68 metric tons and 46·11 metric tons. Three dominant size-groups, 195 mm., 205 mm. and 215 mm., entered the fishery at different periods of the year; of these the 215 mm. group, however, appeared to persist throughout the season except in November 1960. The specimens examined were in maturity stages I and II during the season.

A preliminary examination has been completed of the scales of 483 mackerel specimens during the year. The material was drawn from different centres on the West Coast from Karwar in the north to Vizhingam and neighbourhood in the south. It was found that at all the centres, specimens below 220 mm. in total length showed no indications of rings in their scales. A small percentage in the 220–229 mm. group showed the rings in the Karwar and Mangalore samples while in the Calicut samples even this group was completely devoid of rings. Rings occurred in specimens of all the centres in the 230–239 mm. group though there was a variable percentage of specimens without rings also. It may be assumed that rings were present in the scales in practically all specimens at all centres in the size-groups of 240 mm. and above, although a few of these (particularly from Vizhingam) had also to be classified as " not clear " or " doubtful " and require more detailed examination.

Examination of data on the racial studies of mackerel was continued. Some of the body characters of the Andamans and local samples were compared; slight variations were noticed in some of the body proportions between the two samples. The proportion of the body weight at ventral origin to the body length was found to be mostly above 4·0 in the Andamans sample and mostly below 3·8 in the local sample. The caudal portion appears to be longer in the Andamans sample than in the local sample. The length of the mandible and the height of the body at anal origin were found to be more or less the same in the Andamans specimens while in the local sample the former measurement was found to be slightly more than the latter.

The work on the anatomy of the mackerel was also in progress during the year. A detailed study on the skeletal system has been completed. The main skeletal features in which the Indian mackerel differs from the other forms of mackerel have been noted.

In the digestive system, the arrangement of the hepatic caecae and the shape of the liver appear to have significance from the systematic point of view.

(*e*) *At Ernakulam.*—The mackerel fishery was of moderate magnitude during the year, but showed clear improvement over that of the previous year. The peak landings occurred during the October–December period. The bulk of the landings were made by the gill-net units. Boat-seine, shore-seine and purse-seine operations accounted for a lesser share of the catches. Stray members of mackerel occurred in the trawl catches from 15–17 fathom area off Cochin during the December–March period. There was also an organised backwater fishery in the Cochin backwaters for the first time during January and February.

Length-frequency studies showed that in April and May the modal size was 210 mm. Juveniles in the range of 110–150 mm. started appearing in the trawl catches in May from the 8–10 fathom area off Cochin. During July and August fish of the modal sizes 130 and 160 mm. respectively appeared in the boat-seine catches. In September the modal size was 190 mm. The fishery of October and November was supported by the 200 mm. modal size. From December to March the mode remained steady at 210 mm.

The male to female ratios were 36: 64, 49: 51, 53: 47 and 44: 56 respectively for the 1st, 2nd, 3rd and 4th quarters of the year. The mackerel

examined during April–June were mostly in maturity stages III–IV. Specimens examined in the January–March period showed proof of " spent resting " condition of the gonads. One spent female was available in March with a few large residual eggs in the ovary.

Food studies were continued. Feeding was moderate to good from April to September. Active feeding was noticed from October to March. Copepods predominated among the food items. A wide variety of diatoms and dinophysids were also met with in the stomachs in smaller quantities. Some of the juvenile mackerel (150–160 mm.) examined in June fed exclusively on fish post-larvæ.

(*f*) *At Vizhingam.*—The estimated total landings of mackerel at Vizhingam during the season of 1960–61 were 42,391 kg. this showing a slight decline over the landings of the previous year. The estimated landings were 1,241 kg., 28,279 kg., 5,777 kg. and 7,094 kg. respectively for the four quarters of the year. Well over 50% of the total catch of the season was landed during the second quarter. Shore-seines, drift nets and boat-seines accounted for the major portion of the catch. A small quantity of the fish was landed by hooks and lines.

The size-range in the commercial catch was 45–280 mm. During the second quarter mackerel of 190 mm. total length dominated the landings. Two distinct modes were evident during the third quarter, namely, at 70 mm. and 205 mm. The 230 mm. group was predominant during the last quarter.

Both phytoplankton and zooplankton organisms were noticed in the gut contents in addition to fish remains. *Phyllosoma* larva, *Alima* larva, *Cypris* larva, copepods, other crustacean remains, bivalve larvae, gastropod larvae, *Skeletonema costatum* and *Nitzschia* were observed in the stomach contents.

(*g*) *At Porto Novo.*—As in the past year, the August–September fishery for mackerel was a total failure this year also, the fish having occurred in the catches on two solitary occasions. However, the catches in the preceding summer were very considerable though of short duration (March end to June) compared with the previous year, thus accounting for 19,134·89 kg. out of the total year's mackerel catch of 20,187·89 kg. *Thoorivalai, edavalai, nanduvalai, valavalai* and cast-net were the gear used for mackerel fishing.

Data on length frequency indicated a fall in the dominant size-range from 200–240 mm. of last year to 190–200 mm. There was no appreciable

difference in the sex composition of the population from that of the preceding years and the bulk of the landings were composed of individuals in stage VI (*a*) of maturity. At the peak of the fishery, there was much of night fishing very close to the shore (within 5 fathoms). The few oozing females that were obtained came from the night catches, from nets that operated beyond the 10 fathom line. Comparison of day and night catches pointed to the possibility of the spawning activity being intense during the early hours of the night. Intensified efforts to artificially fertilize the oozing eggs did not yield results. While evidently the summer mackerel fishery coincided with the spawning season of the fish, regular samples of inshore plankton (from the same area where fishing was intense) analysed during the period did not contain any fish eggs that could be reasonably attributed as belonging to mackerel.

Feeding was very intense and almost indiscriminate throughout the season, during day as well as night. Gut contents largely reflected the composition of inshore plankton and its fluctuations.

3. *Prawns and Lobsters*

(*a*) *At Kandla*.—The prawn fishery of Cutch, composed chiefly of *Metapenaeus monoceros*, has been a total failure during this year unlike the bumper fishery of the previous year. This is believed to be more or less a direct influence of the failure of the monsoon this year and the high salinity of the water in the creeks.

Table V shows the dominant size-groups of the species occurring at the various fishing centres.

A new size-group was entering the fishery in June and October 1960 which was composed of small individuals (51–60 mm.). The larger individuals (91–100 mm.) were seen in the fishery for a brief period as in April and December 1960. At Tuna-Sangat the dominant size-range of the individuals constituting the fishery was 56–115 mm. At Luni where observations are available from August to December it was seen that *M. monoceros* occurred in considerable numbers only during August (91–95 and 111–115 mm.) and September (71–75 mm.). It was dwindling in numbers in October (91–95 mm.). At Mandvi, the outermost observation on the Cutch coast, *M. monoceros* were rare throughout the period of observation, *viz.*, October–December 1960 except in November 1960.

The bigger size-groups are found in the catches as one proceeds from the inner to the outer gulf which is suggestive of migration of *M. monoceros*

from the inner creeks to the open sea at a time where the individuals attained a dominant size of over 60 mm. The individuals also disappeared from the inshore waters after they attain a size-range of 111–115 mm. or so. It is also observed that there is no uniform progression in the modal length of this prawn throughout the year which is due to the entry of new size-groups into the fishery.

TABLE V

	Surbari	Kandla	Tuna-Sangat	Luni	Mandvi
	mm.	mm.	mm.	mm.	mm.
April	.. 26–30	96–100	No data	No data	No data
May	.. 31–40	66–70	66–70	No data	No data
June	.. 41–50	51–55	56–60	No data	No data
July	.. No data	56–60	61–65	No data	No data
August	.. 56–60	56–60	56–60	91–95 and 111–115	No data
September	.. 51–55	61–65	71–75	71–75	No data
October	.. 31–35	51–60	76–80	Rare 91–95	Very rare
November	.. 26–30	61–65	76–80	Absent	71–75 and 81–85
December	.. 31–35	91–100	91–95	Absent	Very rare
January 1961	.. No data	66–75	91–95	No data	No data
February	.. No data	No data	Very rare	No data	No data
March	.. 21–30	76–85 and 51–60	Rare 111–120	Very rare	No data

The prawn fishery at Adesar camp which is situated in the little Rann of Cutch, still interior to Surbari, lasted from September to December. At this place there is a lake-like formation whose source has been the river-water. This generally has connexion with the creek at Surbari during July–September under normal rainfall and becomes land-locked in October as the rains come to an end. But in the present year under report this area was

land-locked during the monsoon period itself as there was no sufficient rains to establish prolonged connexion with the creek. The prawn fishery of Adesar camp is due to the migration of the prawns—*M. monoceros* with the lake-like formation from the creek during a spring tide following the first showers when the water in the lake was extremely spread enough so that the creek could establish connexion into the lake during the spring tide. Later with the gradual drying up of the water, it has been completely cut off from the creek. The salinity of the water at Adesar camp ranged from 5·22‰ in August to 38·9‰ in December. The dominant size of *M. monoceros* was as follows in different months:

September	October	November	December
106–110 mm.	116–120 mm.	121–125 mm.	121–125 mm.

Females of this prawns measuring 135 mm. to the maximum observed size of 146 mm. were in immature condition or early maturing stage and the ovary was not well developed also. The same species of prawn of a similar size-range caught from the marine environment during January–March in stray numbers showed better developed ovary and was in late maturing stage.

Observations as the prawn landings are available during the period August–December and March at Luni and during October–December at Mandvi. It is of interest to note that the quantitative composition of the catches in the water gulf region (Luni and Mandvi) was distinct from that of the inner gulf. The catches from the latter (Surbari, Kandla and Tuna-Sangat) are dominated by *M. monoceros*. The other types of prawns noticed in the fishery were *Leander stylifera*, *Metapenaeus brevicornis* and *Penaeus indicus*. At Luni *Metapenaeus brevicornis* and *Penaeus indicus* dominated the catches *Monoceros* was noticed in considerable numbers during August–September. At Mandvi the prawn fishery was constituted by another species of *Leander*, *Hippolysmata* sp. and *Parapenaeopsis sculptlis* in October, *Acetes* sp. and *M. brevicornis* in November and *M. brevicornis* and *Parapenaeopsis stylifera* in December. *M. monoceros* was rare throughout. This difference in the quantitative composition of the catches may perhaps be related to the nature of the sea bottom as in the inner gulf it is primarily muddy while on the outer gulf it is primarily sandy.

(*b*) *At Bombay : Inshore Fishery*.—Study of the inshore prawn fishery of this region by analysis of regularly collected weekly samples from the

commercial catches of the 3 centre, *viz.*, Arnala, Versova, and Sassoon Docks was continued as before. Two types of bag nets, the larger ' dol ' nets and the smaller ' bokshi ' are the gear used in the fishery. The operation of the larger type continued throughout the year at Sassoon Docks, but was suspended at the other 2 centres during the monsoon period. The ' bokshi ' was worked practically all the year round close to the shore at Versova and Arnala.

About 25 species of prawns and shrimps have been recognized in the commercial landings so far out of which about 8 are important, contributing significant proportions of the catches at various times. The occurrence of the others has been rather unsteady and all of them together may account for only a small part of the landings.

Among these 8 species *Palaemon* (*Leander*) *tenuipes* seems to occupy the first place. Excepting October, November and December in all the other months it has formed a fairly high percentage, even beyond 60% in April and May. In these months on some days it formed up to 90% of the Versova and Arnala landings. The bulk of the catches consisted of adult prawns 40–60 mm. in length.

Acetes indicus probably stands second in abundance when the entire year is taken into consideration. It was caught in ' dol ' nets operated near the shore at Versova and Sassoon Docks. In June, it contributed the bulk of the landings at Sassoon Docks. At Arnala, however, the landings were insignificant.

Metapenaeus affinis.—Though fairly good quantities were caught in the months of September, October and November it was much less in abundance than in the corresponding period of last year. During the months of abundance most of the prawns caught were adults measuring 100–150 mm.

P. hardwickii, *P. sculptilis*, *P. stylifera*, *Solenocera indicus* and *Hippolysmata ensirostris* were the other species caught in fairly good numbers in various months. *P. sculptilis* was a conspicuous element in the catches of the ' bokshi ' net at Arnala, but in the other two centres it occurred only in small numbers. Besides these species another, *viz.*, *Atypopenaeus compressipes* sometimes formed the major portion of the prawn landings at Versova in January and the two following months.

Off-shore fishery.—Off-shore fishing operations of the Government of India vessels continued throughout the year, using different types of nets.

Their catches consisted of a variety of species along which *P. indicus*, *P. pencillatus*, *M. monoceros*, *M. affinis*, *P. stylifera* and *P. sculptilis* seem to be more important.

Biological data relating to these species particularly of *M. affinis* were collected as usual. Feeding of *M. affinis* was noted to be not active in September and January–March. Sex ratio varied from week to week; but on the whole females showed a slightly higher percentage. The species seems to be a continuous breeder; but November and December and March–May form the period of maximum activity. It is likely that the species may live for over three years. The fat contents of the muscles have been noticed to vary with the stages of maturity of the gonads and sex.

(*c*) *At Mangalore.*—The inshore prawn fishery in the Mangalore area was comparatively more or less a failure during the year under report. At Ullal the landings were poor during September and October and later in the year there was practically no catch of prawns. *M. dobsoni* was the dominant species at Ullal; at other centres *P. stylifera* and *M. dobsoni* were both prominant.

Mechanised vessels using otter trawls landed fairly good catches. The Government of India trawlers 'Durga' and 'Tarpon' also operated off Mangalore at depths ranging from 8–21 fathoms during the period 21–11–1960 to 2–3–1961. *P. stylifera* dominated the catches from November to March; previously the dominant species was *M. dobsoni*. *M. affinis* and *P. indicus* occurred only in smaller numbers. The capture of a good number of mature and impregnated females of the former in April 1960 and also from November to February 1961 may provide some indication of the breeding period of the species in the region.

The Japanese fishing vessel "Kaiko Maru" surveyed the waters off Mangalore and Karwar coasts from 25–1–1961 to 27–2–1961 between 10 and 64 fathoms. The prawn catches were poor. *M. monoceros* contributed 69·8% of the catches. *P. stylifera* and *M. offinis* also occurred in appreciable numbers.

Group fishing conducted on 25–2–1961 by 'Kaiko Maru', 'Durga' 'Tarpon' and the Training Centre boat showed an interesting feature in the distribution of prawns. *M. dobsoni* did not occur beyond 10 fathoms whereas *M. monoceros* was rare within 10 fathoms.

(*d*) *At Ernakulam : Off-shore fishery*—The off-shore catches by the mechanised vessels operating from Cochin were composed, as usual, of a

number of species with different species dominating from month to month. *M. dobsoni*, *M. monoceros*, *M. affinis* and *P. indicus* were the more common species. Good numbers of *P. monodon* along with large-sized *P. indicus* were caught 10–12 miles South-West of Cochin in the 15–20 fathoms area during November, which is rather unusual.

A study of the fauna associated with prawns in the fishing grounds has been started from the beginning of this season. A number of crabs, sand lobsters and *Squilla* sp. were always found along with prawns. In addition the flat fish *Cynoglossus semifasciatus* was also frequently present.

Palaemon carcinus.—Observations were continued on the fishery and biology of *P. carcinus*. At the 2 centres of observation the trend of fishery followed the same pattern during this season. From June the catch increases and reaches a peak in August. There is a considerable fall in September; but in the following month it again improves and finally declines in November and December.

Analysis of length-frequency data seems to indicate that males belonging to 2-year classes are common in the commercial catches; but in regard to females only one-year class is represented. Males were more in number at the beginning, but as the season advanced the number of females steadily increased and by August they were more. From October an attempt was made to ascertain the distribution of the species at certain centres along the Pampa River. Except at one point, where juveniles were present, at all other centres those caught were adult males probably indicating that females belonging to the same year class had all descended to reach the breeding grounds and eventually got caught.

(*e*) *At Colachel*.—Observations on the lobster and prawn fisheries of the Kanyakumari District were continued during the year under report.

The lobster fishery restarted this year a little earlier than usual, in the second half of November. The catch, however, does not appear to have been large. In December the fishery was brisk and the estimated total landings were slightly better than those of 1959, though not even half of that of the corresponding month of 1958. In January 1961 the estimated total landings were not so good as those of the previous month. The data relating to the landings of the following month are rather incomplete. In March the total landings seem to have dropped still further and at both Colachel and Muttom only basket traps were used in their capture. The estimated totals for each month during the current season are furnished below in tabular form together with those of the corresponding months of the various season to

facilitate comparison. On the whole the landings have shown some improvement over that of 1959–60.

	Colachel		Muttom	
	1959–60	1960–61	1959–60	1960–61
December .	6,954	7,525	17,718	18,160
January ..	5,536	4,489	9,842	13,746
February ..	1,919	..	5,586	..
March ..	745	1,064	1,138	2,298

In the last annual report it has been pointed out that lobsters belonging to larger length groups of over 200 mm. were proportionately much less than in the previous year. This tendency does not seem to have persisted in the year under report though no marked improvement either has been noticed.

The percentage of berried females caught at Muttom is definitely more in all the months except December than in the last season; but at Colachel the opposite is the case.

Prawn fishery.—The prawn fishery along the Kanyakumari District started in May; but the landings were rather poor. The catches of ' Vala Valai ', one of the types of gear used in thsee parts for the purpose, consisted almost exclusively of *P. indicus*. In the *thattumadi* (a type of boat-seine) small quantities of *P. stylifera* and stray individuals of *M. monoceros* were also caught.

It improved considerably in the next month and extended northwards up to a few miles south of Vizhingam. Though correct statistics of landings are not available the catches seem to have been fairly good judging from the numbers the two freezing companies operating here were able to collect. In the following quarter also the fishery remained active with hardly any change in the composition of the landings. In a collection of prawns numbering over a lakh sorted at the Southern Fisheries Corporation Unit at Muttom 0·81% was made up by *P. monodon*, 0·07% by *M. affinis* and still less by *P. carinatus*. Over 99·0% was contributed by *P. indicus* alone. The vast majority of prawns belonging to the last-mentioned species were over 140 mm. long, well beyond the size commonly observed in brackish water catches.

The fishery seems to have come to a close at practically all centres of the District by the middle of October in the third quarter. Towards the close of the season the shore-seine, locally called *kara madi* was also in use at some centres and at Colachel the *netholi valai*, in common use there during the month seem to have captured small quantities of *Acetes* and young ones of *P. stylifera*.

(*f*) *At Madras.*—The fishery and biology of prawns of Madras and the Ennore and Pulicat lakes continued to be studied as before. No well-marked season of abundance was noticeable at Madras and the fishery showed great fluctuations. The boat-seine (*Thuri vala*) was the chief type of gear used in waters 10–25 metres deep. *P. indicus* was the most abundant species, comprising 80–100% of the catches. The rest was usually made up of *M. dobsoni*, *M. affinis* and *P. stylifera*.

At Ennore fishing was done mainly by cast-nets in depths of 3–6 metres, catches varying from 5 kg. to 25 kg. per day. *P. indicus* was the main species caught.

Pulicat lake with its unbroken connexion with the sea throughout the year has proved to be a rich fishing ground for prawns. Stake nets operating at nights in shallow water, 3–10 metres have caught fairly good quantities of prawns, especially in the last 2 quarters. *P. indicus* and *M. monoceros* made up the bulk of the catches in all months. *P. carinatus* and *M. dobsoni* occurred in quite small numbers.

Study of marine plankton for tracing life-histories of prawns was also continued.

4. *Malabar Sole*—Cynoglossus semifasciatus

The fishery of the Malabar sole, *Cynoglossus semifasciatus*, at Calicut was better during 1960–61 than in the previous year; the month of peak commercial landings was September (as is usual along this coast) unlike last year when the fishery was delayed and the peak catches were obtained in October. The total estimated catch of the first quarter at Calicut (Velleyil) was 9·26 metric tons; in the second quarter the total was 484·5 metric tons, all of this being landed in September alone; in the third quarter the estimated landings showed a steep decline to 24·6 metric tons (including the catches reported from locally operating mechanised boats) while in the fourth or last quarter of the year, there was only some negligible landings of this fish at this Centre.

The boat-seines *thattumvala* and *paithuvala* were the two gears that yielded all the sole catches of September, the former accounting for as much as 456·9 metric tons out of the total of 484·5 metric tons. The fishery (of September) was intermittent and unsteady.

Departmental *paithuvala* collections were continued normally once a week throughout the year and these yielded material for length-frequency and maturity studies even after the season of the commercial fishery. Two modes were noticed in the length-frequency curve for September, one at 110–119 mm. and a less dominant one at 140–149 mm. 57·6% of the catches of this month was estimated to fall in the length groups between 110 mm. and 129 mm. while 21·7% was estimated to fall in the length groups of 140 mm. and above. Juveniles of the new brood began appearing in the catches from the second week of November and these formed the mainstay of the fishery during the rest of the year.

The September fishery consisted mainly of individuals in stage IV of maturity. Further advanced stages appeared in gradually increasing numbers in the succeeding two months but as juveniles entered the fishery even in November, it would appear that spawning commenced much earlier than usual and most probably in the off-shore waters. Indeterminates and stage I individuals dominated the catch from November to March, though occasional stage II individuals were also encountered in the new year class in February and March. Spawning appeared from the trend of occurrence of the juveniles in the catches that the period of peak spawning was in the third quarter of the year.

5. *Mullets*

Based on the continued biological studies on the two common species of mullets around Mandapam, *viz.*, *Mugil cephalus* and *Liza macrolepis* with special reference to their growth-rate certain broad generalizations are made.

M. cephalus.—The fishery consists of juveniles (about 75–305 mm. LCF), their recruitment at about 75–145 mm. (LCF) size taking place in January; the older size-group fails to occur in the catches by about April and thereafter. Those beyond 200 mm. (LCF) are in I–II stages of maturity. This appears to spawn once in a year for a brief period. Favourable fishing season is from January to May-June. Growth in a calendar year for the juveniles is about 160 mm. It is a bottom feeder subsisting on foraminifera mixed with decayed organic matter and certain filamentous matter. It harbours the larval nematode parasite (genus: *Panisakis*) in the body cavity.

The length-weight relationship was worked out.

L. macrolepis.—The fishery consists of juveniles, maturing and spent adults. The recruitment, at about 75 mm. (LCF) size, extends from December to June-July. Maturing and spent fish ranging from 186–313 mm. (LCF) are regularly caught in the sea, their peak season being from June to August. Food of juveniles is basically same as those of *M. cephalus*. But maturing and spent fish feed mainly on harpactecoid and cyclopoid copepods and diatoms, food of the fry consists of *Pleurosigma*, *Navicula* and *Nitzchia*.

Studies on this apparent shift in the food habits from immature to maturing and spent stages; maturity studies by measurement of ova-diameter and growth-rate by length-frequency and scale studies are under progress.

6. *Tunnies*

In addition to the completion of the work and consolidation of the data on the biology of the skipjack (*Katsuwonus pelamis*) of Minicoy with special reference to its spawning and feeding habits and the biology of Minicoy principal tuna bait *Lepidozygous tapeinosoma*, the following works were also done at this centre.

With a view to gather some information on the probable causes of fluctuations of tuna fishing at Tuticorin in the light of the biology of tunnies the following data on two important species of tuna *E. affinis* and *N. macropterus* were collected—the length frequency, length-weight relationships, sex ratio, morphometric measurements, etc.

There were good landings of tunnies at Tuticorin from July to November 1960 by the boat/whiffing live unit the composition consisting mostly of *Euthynnus affinis* and *Neothunnus macropterus* and occasionally *Auxis thazard*. It was interesting to note that when most of *E. affinis* had gonads of both sexes in the IV and V stages those of *M. macropterus* contributed to the fishery were males in the immature stages. *Kishinoella tonggol* also were landed in good numbers.

7. *Molluscs*

Studies on the seasonal gonadial variation of the adult pearl oysters, started during the beginning of 1960 could not be continued after the end of the pearl fishery season due to want of regular supply of specimens. Gonads of the oysters examined during the months of April and May were found to

be almost full with ripe reproductive elements in the follicles. In the month of May a few oysters were also found to be partially spent. Pearl fishery commenced at Tuticorin on 22nd March 1961 and is likely to continue up to the middle of May 1961. More than 1,500 divers are engaged in this fishery and an average of 3 lakhs of oysters are fished every day. Samples of pearl oysters are regularly purchased from the retail market during this pearl fishery season also and are measured and the condition of the gonads noted.

During November-December the underwater survey of pearl and chank beds (collaboration work) was continued when Dr. F. B. Salvadori, F.A.O. Underwater Expert, was in Tuticorin. In the absence of a suitable launch work was commenced from the northern area of the central sector. A total number of 150 stations were fixed and the nature of the bottom and depth were recorded. As the sea became very rough towards the beginning of December, the work was discontinued after the middle of December.

B. Off-shore Fisheries Investigation

(a) At Bombay

During the period under report areawise analysis of the fishery data collected by the off-shore fishing boats at Bombay was completed for the year 1960. Seven vessels of the Government of India, Deap Sea Fishing Station, were carrying out fishing operations in 1960; out of these only M.F.V. *Jheenga* worked in all the months of the year. The operations of the other vessels, *viz.*, M.F.V. *Bumili* (11 months), M.F.V. *Bangada* (4 months), M.F.V. *Champa* (5 months), M.L. *Sagar Pravasi* (6 months), M.L. *Sagarkanti* (3 months) were restricted to some months of the year. With the exception of one long-line trip by M.F.V. *Bangada* in April 1960 and six daily gill-net trips by M.F.V. *Meera* and M.L. *Sagarkant* in October, 1960, all the other operations were carried out with trawl nets. These vessels were mostly working in areas nearabout Bombay and occasionally off Saurashtra coast. All these seven vessels put together landed a total catch of 428,471 kg. of fish in 1960 whereas the two pairs of Bull trawlers of the New India Fisheries Limited landed during the same period 4,247,960 kg. of fish.

The Bull trawlers of the New India Fisheries Limited continued to work throughout the year. During this year they worked in 29 areas lying between area '43' and area 'Z' and landed a total catch of 4,248,060 kg. of fish spending a total effort of 5,167·50 hours of actual fishing. Overall average catch-per-unit-effort worked out to 822 kg./hr. The most salient feature of this year's operation is that these boats have extended their operations

to the northernmost areas (Q, R, S, T, U, V, X, Y) which were not systematically sampled so far. The fishing operations in this virgin area were generally successful with the result it is seen that more than 70% of the total effort was expanded there. 'Ghol' and 'Karkara' fishery were particularly good in these areas. The Dwaraka region (areas K, L, M, N) which is known to yield better catches of 'Dara' and 'Koth' was not fished during this year with sufficient intensity. The fishing effort spent in Veraval region (areas 2 and 3) and in Porbunder region (areas A, B, D, E, H, I) were more or less of the same order as in the previous years. 'Wam,' Cat-fish and 'Ghol' were the important catches from Veraval region while 'Dhoma', 'Ghol', Cat-fish and elasmobranchs predominated the catches from Porbunder region. In Bombay and Cambay regions fishing operations were as usual scrappy.

'*Dara*' (Polydactylus indicus) *investigations*.—'Daras' formed only a small component of the landings of the off-shore fishing vessels this year. The trawlers of the Government of India, Deep Sea Fishing Station, landed 886 kg. of 'Dara' forming 0·206% of their total catches. The bull trawlers of the New India Fisheries Limited landed a total quantity of 86,065 kg. of 'Daras' which amounted to 2·03% of their total catch. The average rate of yield was 16·16 kg./hr. More than 93% of this total quantity of 'Daras' was obtained from areas N, Q, R, S and U in the months of October, November and December. They ranged from 350–850 mm. in length and they were mostly immature; the gonads of the larger fishes being in II and III stages of development in December.

The significant decline in the total catch of 'Dara' this year is perhaps due to the lesser amount of effort spent in Dwaraka region which is considered to be the main 'Dara' fishing ground. Gill-net fishing for 'Dara' started at Satpati and other fishing villages. Detailed investigations are planned for the coming season. Very small (150–200 mm.) juveniles of 'Dara' are obtained in small numbers almost throughout the year in the Dol-net catches of Versova and sometimes in Sassoon Docks.

'*Wam*' (Muraenesox talabonoides) *investigations*.—The Government of India vessels landed a total quantity of 6,706 kg. of eels during 1960. It accounted for 1·56% of the total catch. The New India Fisheries trawlers landed 298,200 kg. of 'Wam' during the same period. The average rate of yield was 57·7 kg./hr. and it accounted for 7·01% of the total catches. The yield of 'Wam' was particularly good from Veraval region. Very large quantities of eels were landed from area 'Q' in the month of August

1960 when an average yield of more than 350 kg./hr. of eels was realised. It was also observed that this catch contained a fair percentage of *Muraenesox cinereus* as well. Size of eels caught by these vessels ranged from 1,220 cm. to 1,700 cm.

'*Koth*' (Otolithoides brunneus) *investigations.*—The bull trawlers of the New India Fisheries Limited landed 31,845 kg. of 'Koth', forming only 0·75% of the total catch for 1960. This is the lowest annual percentage catch of 'Koth' in the trawler landings. Another feature noted was the paucity of adult 'Koth' in the catches of the previous three seasons (1958–61). This and the poor fishery for 'Koth' could be due to two reasons, namely, (i) the lesser exploitation of the recognized Koth-rich areas, and (ii) the lesser amount of the standing crop of 'Koth'. Results of the areawise analysis of the catches show that first is true. The trawlers of New India Fisheries Limited spent only 367 hours out of a total trawling time of 5171 hours in the areas K, L, M and N (Dwaraka region) which have proved to be rich in 'Koth', while the vessels have spent 383 hours in area 'R' in the month of March 1960 alone. It is further seen that whenever areas K, L, M and N were fished fairly good catches of 'Koth' were reported (C.P.U.E. of 199 kg. in February 1960 in area 'K', 154 kg. in January 1960 in area 'K', 100 kg. in December 1960 in area 'K'). The second factor, namely, the lesser amount of the standing crop of 'Koth' cannot be verified with the data available.

The Off-shore Fisheries Station trawlers landed very small catches of 'Koth'.

Studies on the inshore catches of 'Koth' indicate that the fish attains 385 mm. in size at the completion of one-year. Length-frequency distribution of 'Koth' from the catches of the trawlers for past three seasons shows out three modes, at 385, 525/595 and 805/875 mm., which can be said to be representing the I, II and III year classes. This is in agreement with the findings of the study of scales of 'Koth'. 'Koth' of the inshore catches appear to be mainly of '0' and 'I' year class.

Stomach contents of 1565 'Koth' were analysed and the fish are seen to prefer *Acetes indicus*, among prawns and *Coilia dussumieri* and *Bregmaceros macellandi* among the fishes. The feeding intensity of the fish are found to be least during the cold months, November to February, when rings are presumably laid on the scales.

Gonad studies indicate that the 'Koth' probably begin spawning by the end of monsoon period and continue to spawn for about six months, as evi-

denced by the prolonged recruitment of young 'Koth'. The individual fish spawns once a year and exude all ova at one time.

'*Ghol*' (Pseudosciaena diacanthus) *investigations.*—'Ghol' landings of the bull trawlers of New India Fisheries Limited were good this year with an increase of 1,05,542 kg. in the annual catch (0·15%) over that of last year (1959). The percentage of 'Ghol' to total catch this year (1960) is 6·66. The increase in the annual catch of 'Ghol' as well as total catch this year (1960) seems to be due to concentration of effort in the areas P, Q, R, S, T, U, V, X, Y, Z of the Cutch region which had not been fished during the previous years. The peak landings of Ghol were in the months January, February, March and April. From May onwards the catch of 'Ghol' declined and August to October was the period when the landings of 'Ghol' were very poor. From November through December the landings of 'Ghol' gradually increased. This seasonal fluctuation in the catch of 'Ghol' may be indicative of seasonal movements of this species in this region (Maharashtra and Gujarat waters) which has to be studied in detail.

30–50 mm. post-larvae and 50–100 mm. small juveniles occurred from the end of June through July, August in the dol-net fishing at Varsova and Sassoon Docks. 100–150 mm. and 150–200 mm. groups were dominant in September and October, 200–250 mm. group in November and December. From January onwards few juveniles appear in the dol-net catches at Versova and big Ghols are landed in good numbers.

The feeding intensity of juveniles was observed to be high during September to December. Prawns constituted nearly 80% of the stomach contents of the juveniles during this period. *Acetes indicus*, *Parapenaeopsis stylifera*, *Parapenaeopsis* sp., *Solenocera* sp., *Hippolysmata ensirostris* were the important species of Prawns observed in the stomach contents. *Bregmaceros macclellandi*, *Polynemus heptadactylus*, small sciaenids (Doma), *Coilia dussumieri*, *Thrissocles* sp. were the fish items.

The spawning season in this species is protracted extending from June to September. From October to March specimens in stages I, II, III (and recovering I, II, III) were encountered. From April onwards specimens in stage IV appear in the trawler landings as well as local dol-net landings and during May-June most of them were in stage V or early VI. From July to September spent or partially spent and few recovering spents were encountered.

Examinations made on the scales and otoliths of 800 fishes ranging from 50–1,150 mm. showed growth rings on them. The percentage of scales with

minimum marginal growth (circuli count in the terminal zone) is high from August to January, which appears to be the time of formation of the rings in the scales. The translucent rings on the otoliths appear to be formed during the period October to December. The average length of fish showing I, II, III, IV, V, VI, VII, VIII rings on their scales has been found to be 446, 683, 809, 899, 995, 1,043, 1,076, 1,135 mm. respectively. There seems to be a fairly good agreement between the size of the age-groups observed in the length-frequency distributions and the average size of fish having I to V rings on their scales. Thus the modes at 425/475, 675/625, 775/825, 875/925 and 975/1,020 mm. can be taken as representing the age-groups I, II, III, IV and V respectively. The results of studies on otoliths are more or less in close agreement with those scales.

'*Karkara*' (Pomadasys hasta) *investigations.*—Biological studies of *Pomadasys hasta* were continued during this period. For the period January 1960 to December 1960, 469,562 kg. of 'Karkara' were landed by the New India Fisheries Limited and constituted 11·28% of the total catch. 'Karkara' fishery was best in the month of November and the catch-per-unit-effort was 211·47 kg./hour. In April, May and September the fishery was moderate the yield ranged from 32·91 to 88·53 kg./hour while from June to August it was very poor. Good 'Karkara' catches were recorded from the areas R, Q, N and V. The highest catch record for the season was from the area N in the month of February 1960, and the catch-per-unit-effort for the same was 636·61 kg./hour.

The graphical picture of length frequency data shows that in the months of May, January and February there are two modes while in April, June, September, October, November, December and March there is only one mode at different size-groups. Otoliths were studied for growth study and it showed that the otoliths from the fish ranging from 130 to 240 mm. show one ring; 250 to 360 mm. range 2 rings; 370 to 480 mm. size-group 3 rings; 490 to 560 mm. size-range 4 rings and 570 mm. onwards 5 rings.

Analysis of stomach contents showed that majority of stomachs were empty or with a very little digested matter. In the rest of the cases *Squilla*, prawns, crab, etc., in highly digested condition, was noticed in the stomach contents. Occasionally fishes, bivalves, *Echiurus* and polychaetes were also observed in the stomach contents.

From April to June the ovaries of *P. hasta* were observed in advance stage of maturity and in September they were in VI stage. In November-December the ovaries were in spent recovering condition.

'*Bombay Duck*' (Harpodon nehereus) *investigations.*—During 1960–61, 3,988 specimens were measured for length-frequency studies at Versova. In addition, 344 specimens were examined in the laboratory for collecting biological data. Body measurements of 105 specimens from Jaunput (Orissa) were taken and the data remains to be processed for studies on delimitation of stocks.

The results of the investigations carried out during the year confirm the findings arrived at earlier. The following conclusions can be arrived at based on observations made during the last three years, since 1958:

(i) The breeding season appears to be continuous with a peak breeding season lasting three to four months from December to March or so, (ii) The minimum length of the fish at first maturity has been found out to be 210 mm. in total length. (iii) The individual of the species spawns only once a year as seen by the frequency distribution of ova diameter measurements. (iv) The number of mature ova in a fish measuring 210 mm. in total length is considerably less than fish varying between 240 and 280 mm. The range of variation being 14,000–30,000 in smaller and 80,000–140,000 in bigger fish. (v) The data on length-frequency studies support the observations on the breeding season, *i.e.*, continuous breeding as evidenced by the presence of smaller groups throughout the year. As such the length-frequency data have to be carefully studied before determining the age and the rate of growth based on it. (vi) From the pooled length-frequency data for the years 1958–59, 1959–60 and 1960–61 two modes can be made out at 127 mm. and 217 mm. with slight variations. They probably appear to represent the one-year old and two-year old fishes. (vii) Assuming that the fish attains a length of 217 mm. in total length at completion of two years, then it can be said that it attains first maturity at two years of its life. (viii) The commercial catches of Bombay duck along the Maharashtra coast indicate a gradual decrease in landings from 1956 to 1959. The landings during 1956 accounted for 76,458 metric tons as against 27,279 metric tons in 1959 although the fishing method, the fishing grounds and the fishing effort remain more or less the same. During 1960 the fishery was a failure but exact figures are not yet available for comparison. (ix) The catch composition indicates that the fishery is mainly supported by juvenile fishes. Fish beyond the minimum size of maturity accounted for only 18%, 21% and 20% during 1958–59, 1959–60 and 1960–61 respectively. The percentage of fish which might have spawned for the second time during the current year was as low as 10.

(*b*) *At Veraval*

Three off-shore fishing vessels of the Government of India M.L. *Meera*, M.L. *Sagarkanti* and M.F.V. *Bumili* operated from Veraval during the year under report. The results of the operations of these vessels are delineated in Table VI given below. The three vessels between them landed 37,289·03 kg. of fish during the last two quarters of the period M.L. *Meera* recorded the maximum catch followed by M.L. *Sagarkanti* and M.F.V. *Bumili*. M.L. *Sagarkanti* had the maximum number of fishing days (96) followed by M.L. *Meera* (52) and M.F.V. *Bumili* (8).

The landings of the 'Dangri' (*Johnius hololepidotus*) were few and far between during the year. Only 36 specimens ranging in length (870–1,070 mm.) were available for study owing to the paucity of landings.

Fishery biological studies were initiated on the 'Red fish' or 'Sea bream', *Argyrops spinifer* (Family—Sparidae) which formed a sizable part of the catches of M.L. *Meera*. Over 1,100 specimens were measured for length-frequency studies, the length-range being 130–364 mm. For the study of weight-length relationship, data were collected from 123 fish. Ovaries in stage VI (I.C.E.S.) having 'speckled' appearance were collected in December 1960. Studies on food and feeding habits and on growth checks on scales are in progress.

TABLE VI

Showing the results of the off-shore operations during the year ended 31–3–1961

I. M.L. MEERA

Period	No. of fishing days	No. of fishing hours	No. of hauls	Catch per hour kg.	Catch per haul kg.	Total catch kg.
Quarter ending 31–12–1960	35	161–10	138	71·63	83·65	11,544·99
Quarter ending 31–3–1961	17	64–40	47	77·74	106·96	5,027·00

A. Quarter ending 31–12–1960

(i) Areas fished, in the descending order of fishing-hauls within brackets } 21–69 (Off Porbander—November, 1960) 4D; 3E; 3C (12) (3) (2)

Range in depth .. 20·13–38·40 metres.

Gear employed .. (*a*) Larsen Trawl H.R. 46′ F.R. 50′

(*b*) Shrimp Trawl H.R. 39′ 4″ F.R. 30′ 10″

(ii) Areas fished, in the descending order of frequency of fishing hauls within brackets } 20–70 (Off Veraval—November 1960 and December 1960) 6B; 5C; 5B; 6A; 6C; 5D; 1A; 6D (42) (40) (10) (7) (6) (5) (4) (1)

Range in depth .. 23·80–42·80 metres.

Gear employed .. (*a*) and (*b*) as in (i), *plus* Nylon nets.

B. Quarter ending 31–3–1961

Areas fished in the descending order of frequency of fishing hauls within brackets } 20–70 (Off Veraval) 5B; 6B; 6A; 5C (19) (19) (7) (2)

Range in depth .. 23·80–42·10 metres

Gear employed .. (*a*) Larsen Trawl H.R. 46′ F.R. 50′

(*b*) Shrimp Trawl H.R. 39′ 4″ F.R. 30′ 10″

Catch Composition

Sl. No.	Composition of the catch	Weight kg.	Sl. No.	Composition of the catch	Weight kg.
1	'Dhoma'	2,655	15	Red Perch	50
2	'Pervi'	590	16	'Bangada'	35
3	'Ghol'	251	17	'Pallva'	35
4	Prawns	233	18	'Kati'	28
5	Sharks	178	19	'Tam'	22
6	Miscellaneous fish	165	20	'Wakti'	21
7	Rays	130	21	'Koth'	14
8	'Dara'	127	22	'Bakas'	10
9	'Red fish'	100	23	'Surmai'	10
10	'Wam'	94	24	'Pomfret'	8
11	Cat-fish	70	25	'Chand'	5
12	Skates	70	26	'Chor Bombil'	5
13	'Karkara'	67	27	Lobsters	2
14	'Karli'	50	28	Squids	2
				TOTAL ..	5,027

Period	No. of fishing days	No. of fishing hours	No. of hauls	Catch per hour kg.	Catch per haul kg.	Total catch kg.
Quarter ended 31–12–1960	32	185–00	57	22·45	72·87	4,153·51
Quarter ended 31–3–1961	64	277–15	97	25·92	74·07	7,185·23

A. Quarter ended 31–12–1960

(1) Areas fished in the descending order of frequency of fishing hauls within brackets: 21–69 (Off Porbander—November 1960) 4D; 4C; 3D (4) (3) (2)

Range in depth .. 23·80–29·30 metres

Gear employed .. Nylon gill-nets—mesh 5½″—16 pieces

(2) Areas fished in the descending order of frequency of fishing hauls within brackets: 20–70 (Off Veraval—November and December 1960) 6A; 5B; 5A; 6B (28) (10) (5) (5)

Range in depth .. 29·30–51·20 metres

Gear employed .. Same as in (1).

B. Quarter ended 31–3–1961

Areas fished in the descending order of frequency of fishing hauls within brackets: 20–69 (3) (1) 20–70 5B: 6A; 6B; 5C; 5A (43) (20) (16) (10) (4)

Range in depth .. 27·0–49·0 metres

Gear employed .. (*a*) Nylong ill-net—mesh 5½″—16 pieces (in January 1961)

(*b*) Bottom set gill-net—mesh 5½″, 46″—16–17 pieces (in February 4, March 1961)

Sl. No.	Composition of the catch	Weight kg.
1	Pomfret	3,000·22
2	Sharks	1,517·64
3	'Pallva'	922·00
4	Cat-fish	354·50
5	'Ghol'	339·07
6	Miscellaneous fish	187·26
7	'Karli'	185·00
8	Tuna	168·00
9	'Bing'	144·50
10	Leather skin	118·00
11	'Surmai'	71·54
12	'Kati'	35·00
13	'Chand'	18·00
14	'Tam'	17·00
15	'Red fish'	16·00
16	'Rawas'	16·00
17	Mackerel	15·00
18	Sole fish	15·00
19	Rays	14·00
20	'Karkara'	13·50
21	'Wam'	12·00
22	'Koth'	6·00
	TOTAL ..	7,185·23

III. M.F.V. BUMILI

Period	No. of fishing days	No. of fishing hours	No. of hauls	Catch per hour kg.	Catch per haul kg.	Total catch kg.
Quarter ended 31–12–1960	8	39–05	28	240·67	334–94	9,378·30

Areas fished in the descending order of frequency of fishing hauls within brackets } (*a*) 18–72
3D; 4C; 5D; 6D
(3) (2) (2) (2)

Range in depth .. 25·60–40·30 metres

(*b*) 19–72
2B; 2A; 3A;
(2) (1) (1)

Range in depth .. 40·30–49·40 metres
(*c*) 20–69
5F
(2)

Range in depth .. 54·90–58·56 metres
(*d*) 20–70
5B; 5C; 6B
(8) (3) (2)

Range in depth .. 25·60–40·30 metres

Gear employed .. (*a*) Russian Trawl 45′
(*b*) Larsen Trawl H.R. 81′
(Big) F.R. 87′ 3″

(*c*) *At Ernakulam*

Government of India trawlers.—M.F.V. Pratap continued its Otter trawling operations off the coast between Calicut and Cochin but mainly concentrating her fishing effort between Ponnani and Alleppey, as in the previous year, at depth ranging from 24–49 metres. A total of 1,23,417 kg. of fish were landed up to the end of January 1961. The catches were poor in December 1961 on account of heavy concentration of jelly fish between Cochin and Quilon as evidenced by the low catch rate (114·5 kg./hour). The catch varied from as low as 87·9 kg./hour in June to as high as 203·8 kg./hour in January. During April-May the average catch per hour was 168 kg. and during October to December 160 kg./hour. The average catch/hour for the year was 166 kg. which compares favourably with 152 kg./hour in the previous year. But the total effort was less than 30% and a total catch a little less than 50% of 1959–60 figures. Details of catch taken from October 1960 to January 1961 are given below.

	Effort in hours	Total catch in kg.	Catch per hour	Percentage of major categories			
				Small fish	Sharks and rays	Cat-fish	Others
1. Alleppey area	391·6	1,10,734	282·6	71·6	14·6	6·0	1·0
2. Ponnani area	71·2	10,462	146·8	45·8	43·8	9·1	0·4
3. Calicut area	22·3	2,221	98·7	64·4	34·7	..	..

Small fish formed the major catch in all the areas; while cat-fish were taken in good quantities off Alleppey and Ponnani, sharks and rays were abundant in both Ponnani and Calicut areas—a feature observed in the previous years also. Prawns were negligible in all the 3 areas between 24 and 49 metres.

M.F.V. Durga, Samudra, and Tarpon.—Shrimp trawling by these small vessels was mostly confined to areas off Cochin between 5 and 31 metres. Prawns were caught at 54·7 kg./hour in June, practically nil during September and October but varied between 12·2 and 35·26 kg. between November and January and 21·6–27·6 kg./hour during April and May. Small fish, however, formed 90% of the total catch. When the general catch declined in June the prawn catches showed double the yield per hour to the previous months. The total landings in the area amounted to 74,117 kg. of fish.

Two vessels worked off Tellicherry and Mangalore from November 1960 to January 1961 bringing 16,344 kg. and 65,225 kg. of fish respectively. Prawn catches were, however, poor in these areas.

The highest general catch return was obtained off Tellicherry (267·8 kg./hour) but fishing effort was limited only to the first half of November. Mangalore area gave 189·2 kg./hour in November–January as compared to Cochin area where 246·9 kg./hour were recorded for the same period. The relative abundance of the different areas cannot be determined properly unless proper sampling is made throughout the areas during the entire fishing season.

Indo-Norwegian Project Vessels.—Five boats (20 ton vessels) were operating mainly off Cochin for shrimp trawling. Out of a total fishing effort of 1,996·3 hours, 1,420·25 hours (about 70%) were spent south of Cochin and the rest north of Cochin. During March to early May fishing was confined to 6–8 fathom region, but later the boats shifted their activity towards 10–13 fathom depths. From September to October the boats worked in the 20 fathom line. The total landings for the year amounted to over 300 tons with an average yield of 151 kg./hour of trawling. Catches were better in shallower areas from March to May and December onwards. But at the commencement and termination of the monsoon the deeper regions were found more productive. This observation, however, cannot be generalised, at present, as effort is not evenly distributed over the entire region, though the tendency of commercial trawlers is to move towards areas of abundance of the species of fish they are after.

The boats were primarily fishing for prawns and about 90 tons of prawns (30% of total catch) were landed. 29% of annual prawn landings was taken in June 1960 around the 10–12 fathom line and consisted mainly of small prawns—*Metapenaeus dobsoni*. Details of prawn catch, effort and distribution are given below.

Distribution of effort, catch and catch per unit of effort in space.—Areawise distribution of the effort and catch during the year 1960–61

Area	North Cochin	South Cochin	Total
Total catch ..	85,868	215,293	301,161
Prawn .	33,911	56,104	90,015
Total effort ..	576·05 (28·9%)	1,420·25 (71·1%)	1,996·3
C. fish/hour of trawling	149·1 kg.	151·6 kg.	150·9
Prawn c./hour of trawling	58·9	39·5	45·1

The fish were composed of a mixture of small fishes like *Nemipterus japonicus*, *Lactarius lactarius*, Sciaenids, ribbon fish, cat-fishes, *Upaeneus* sp., *Saurida* sp., Soles and juvenile *Serranus*.

Other types of mechanised fishing: *Purse seining*.—During September and part of October by one boat in 8–10 fathom area brought in 14,400 kg. of mackerel and 9,600 kg. of oil sardine. *Trolling line* was employed along with trawling when $2\frac{1}{2}$ tons of seer fish majority of which (2 tons) were landed during September–November. *Hook and line* were chiefly used for Kalava fishing (*Serranus*) by R.V. KALAVA in the 48–50 fathom areas and is said to have given very good results. The data of the operations are not passed on to this substation.

Biology and Fishery of Nemipterus japonicus *and* Lactarius lactarius.—The biology of the two fishes is being studied as ancilliary to the general study of the off-shore fisheries as no significant catches of prime fish are taken by trawling in these regions and these two species constitute the better varieties of fish taken in fair quantities. *N. japonicus* were caught off Cochin at 27–31 metres in good quantities but few in 37–50 metres. 11–14 cm. length groups occurred in April and May while in June younger fish were recorded. In September the modal size was 10 cm., in October 12 cm., and November/December 13 cm. Mature fish occurred during October–February with their peak during October–November. By March only immature fish were met with. Prawns and polychaetes formed the main food items in their diet. Occurrence of *Squilla* in large numbers in gut contents is an interesting feature.

Lactarius lactarius.—About 4,000 kg. were landed by Indo-Norwegian Project Boats during the year, the peak period of occurrence being March–April 1960. The length ranged from 11 to 28 cm. The growth rate between sexes were found to vary, the females having larger modal length than males. Juveniles appeared during January and March and ranged from 7 to 9 cm. The fish was found to be active piscivores with a marked favour for Anchovies. The juveniles of 7 cm. feed mostly on Mysids.

(*d*) *At Tuticorin*

During the year under report frequent trips were undertaken on board the vessels of the Offshore Fishing Station, Tuticorin, for collection of biological data and the catch data of the vessels were analysed and compiled. Four vessels, *viz*., M.L. *Sardinella*, *Meenakshi*, *Sagar Suhdari* and *Meenalochani*, were operating during the year. Bottom set gillnets, shrimp trawls, long-lines, drift-nets and R.C. hooks were used.

Bottom-set gill nets.—Bottom-set gill netting was done mostly off Tuticorin (Area 8-78/50) and on a few days near Cape Comorin (Area 8-77/10). The nets, usually 10–12 in number, were set in the evening and hauled up in the morning and hauled up in the evening. The latter sets consistently produced poorer catches, presumably due to the greater visibility of the nets during daylight hours. The details of catch, effort and catch-per-unit-effort of all the vessels operating bottom-nets are summarized below for each area separately.

Area 8-78/5 B, *Depth fished* 3–8 *fathoms*

	No. of sets	Total kg.	Catch/set kg.
April 1960 ..	28	1,454	51·9
May ..	45	833	18·5
June ..	34	835	24·6
July ..	31	1,001	32·3
August ..	39	1,601	41·1
September ..	41	1,332	32·5
October ..	66	2,929	44·4
November ..	30	1,776	59·2
December ..	17	1,428	84·0
January 1961 ..	34	1,884	55·4
February ..	30	1,869	62·3
March ..	25	1,296	51·8

It will be seen that bottom-setting yielded a fairly good catch throughout the year though the period November to April was more productive:

The percentage composition of the important fishes caught in the nets are given below for each quarter:

	April, May, June 1960	July, Aug., Sept. 1960	Oct., Nov., Dec. 1960	Jan., Feb., March 1961
Sharks ..	28·5	51·9	30·5	54·1
Skates ..	1·2	5·3	15·5	1·2
Rays ..	11·3	7·0	3·5	22·4
Chorinemus ..	17·3	5·4	2·5	0·98
Arius ..	18·4	0·4	17·9	16·1
Sciaenids ..	6·3	6·5	6·5	9·1
Perches .	3·1	8·5	2·3	0·46
Chirocentrus ..	0·85	3·7	1·2	0·33
Polynemus ..	1·1	7·2	3·1	1·1

Elasmobranchs occurred throughout the year in good quantities and made up a large proportion of the catch. Chorinemids represented mainly by large specimens of *Chorinemus lysan* (10–13 lb.) occurred in good number only during the first quarter. Ariids, mostly large specimens of *Arius dussumieri* (5–8 lb.), occurred mainly during the first and last quarters and sporadically during the third quarter. *Polynemus indicus* occurred mainly during the second and third quarters.

Area 8–77/1–10, depth fished 7–11 fathoms. Bottom-setting was done only during February and March.

	No. of sets	Total catch kg.	Catch/set kg.
February ..	3	293	97·7
March ..	2	127	63·5

Catch composition.—Sharks 37·3%, *Arius* 20·5%, Rays, Sciaenids 8·7%, *Chorinemns* 3·5%, *Caranx* 2·4%, Miscellaneous 18·3%.

Shrimp Trawls.—Shrimp trawling was done mostly off Pinnakayal (Area 8–78/48) and Devil Point (Area 8–78/5-B) and occasionally off Overi (Area 8–77/2 F), Idinthakarai (Area 8–77/1 E) and Cape Comorin (Area 8–77/1 D) and Nallathanni thivu (Area 9–78/1 D).

For each area the total effort put in by all the vessels, the total catch and catch per trawling hour are summarized monthwise below: Shrimp trawling was done only during daytime.

Area 8–78/4 B, *Depth fished* 7–12 *fathoms*

	Trawling hours	Total catch kg.	Catch/hour kg.
June 1960 ..	90–50	3,855	42·0
July ..	171–35	7,379	42·0
August ..	210–30	15,729	74·7
September ..	188–20	19,846	105·4
October ..	145–40	16,196	111·7
November ..	212–40	18,579	87·3
December ..	77–10	4,381	56·8
January 1961 ..	12–20	295	23·9
February ..	30–40	887	28·9
March ..	82–25	2,509	30·4

It is seen that the second and third quarters were the most productive periods at Pinnakayal, the last quarter being the poorest.

Percentage composition of fishes caught in the shrimp trawl is given below for each quarter.

	April, May, June 1960	July, Aug., Sept. 1960	Oct., Nov., Dec. 1960	Jan., Feb., March 1961
Prawns ..	30·0%	22·0%	12·1%	18·5%
Sciaenids ..	21·3	26·4	32·9	30·4
Leiognathids ..	9·5	6·5	15·2	20·0
Cynoglossus ..	3·9	6·9	7·4	4·2
Pomadasys ..	15·7	5·6	5·5	5·2
Polynemus ..	Traces	8·4	8·9	Traces
Miscellaneous ..	19·6	24·2	18·2	21·6

Prawns occurred in good quantities during the first two quarters and then dwindled in number. *Metapenaeus dobsoni*, *M. affinis*, *Penaeus carinatus* and *P. indicus* were the important species arranged in the order of abundance. Small Sciaenids mainly *Pseudosciaena* since *Umbrina* formed the major component of the fish catches, all through the year. The Leiognathids came next in importance. The miscellaneous fraction was made up of Elasmobranchs (mostly skates and rays), clupeids (mainly *Opisthopterus* and *Thrissocles*), *Trichiurus* and *Therapon*. The common polynemid was *Polynemus heptadactylus*.

Area 8–78/5 B, *Depth fished* 3 *fathoms*

	Trawling hours	Total catch kg.	Catch/hour kg.
December 1960 ..	14–45	812	55·1
January 1961 ..	69–10	2,418	34·9
February 1961 ..	62–10	1,195	19·2
March 1961 ..	32–00	184	5·8

Catch composition.—Prawns 19·3%, Crabs 14·3%, Sciaenids 20·6%, *Cynoglossus* 8·1%, Clupeids 15·3%, *Leiognathus* 2·6%, Miscellaneous 10·6%.

Metapenaeus dobsoni and *M. affinis* were the important prawn species. The crabs were *Neptunus pelagicus*, *N. sanguinolentus* and *Scylla serrata*. The Sciaenids consisted of *Pseudosciaena sina*, *Umbrina russelli*, *U. macroptera*, *Sciaenoides microdon*. The important clupeids were *Opisthopterus*, *Coilia* and *Thrissocles*. The crabs, clupeids and *Cynoglossus* were relatively more important and the Leiognathids and *Pomadasys* less so in the Devil Point catches when compared to those of Pinnakayal.

Area 8–77/2 F, *Depth fished* 5–7 *fathoms*

	Trawling hours	Total catch kg.	Catch/hour kg.
December 1960 ..	3-05	39	12·6
February 1961 ..	10–55	444	40 0

Catch composition.—Leiognathus 48·5%, Sciaenids 29·1%, Clupeids 9·7%, Rays 3·0%, Miscellaneous 9·7%.

The catches in the Overi area were made up mostly of *Leiognathus* and Sciaenids. Among the latter *Pseudosciaena axillaris* was the most common species. Prawns formed a very small fraction of the catch.

Area 8–77/1 *E. Depth fished* 5–31 *fathoms*

	Trawling hours	Total catch kg.	Catch/hour kg.
February · ..	4–05	286	70·0

Catch composition.—Prawns 9·0%, *Arius* 8·0%, Sciaenids 24·5%, Clupeids 32·6%, Miscellaneous 25·9%.

Area 8–77/10, *Depth fished* 5–13 *fathoms*

	Trawling hours	Total catch kg.	Catch/hour kg.
February ..	5–50	29	5·0
March ..	6–10	5	0·8
		Area 9–78/10	
December ..	1–30	2	1·3

The catches in the last two areas were very poor during the months fished.

Long-lines.—Long-lining was done off Tuticorin (Area 8–78/5 B) and Cape Comorin (Area 8–77/10). The details of catch, effort and catch-per-unit-effort are summarized below. Area 8–78/5 B. Depth fished 5–11 fathoms.

	No. of hooks operated	Total catch kg.	Catch/100 hooks
1st Quarter ..	3,495	343	9·9
2nd Quarter ..	1,625	138	8·5

Catch composition for the two quarters.—Sharks 30·2%, Rays 32·8%, Perches 6·8%, Carangids 3·6%, Miscellaneous 26·6%.

Area 8–77/10, *Depth fished* 5–7 *fathoms*

	No. of hooks operated	Total catch kg.	Catch/100 hooks kg.
February ..	200	60	30·0

Catch composition.—Sharks 10·5%, Rays 67·2%, Skates 22·3%.

Drift-nets.—Drift-netting was done in the night off Tuticorin (Area 8–78/5 B) only. The details are given below.

	No. of sets	Total catch kg.	Catch/set kg.
1st Quarter ..	39	383	9·9

Catch composition.—Euthynnus 33·3%, Sharks 22·4%, *Arius* 11·8%, *Chirocentrus* 8·8%, *Scomberomorus* 7·0%, miscellaneous 16·7%.

R.C. Hooks.—R.C. hooks were operated off Tuticorin only on three days. A large tiger shark (*Galeocerdo*) was the only fish caught.

	No. of hooks operated	Total catch kg.	Catch/100 hooks kg.
June ..	126	77	60 8

(*e*) *At Waltair*

During the year the vessels, six in number, made a total of 579 voyages, making a total of 1,027 hauls in 4161 hours. They caught an average of 231·5 kg./day; 143 kg./haul, and 33 kg./hour of fishing, a total of 1,46,354 kg. were taken in all, and this fetched Rs. 54,216·36 nP. in the market. Table VII gives details of this data, which is based on a series of *exploratory* hauls to ascertain the fishing grounds off the coasts of Orissa and Andhra Pradesh.

Although there are still several hundred square miles of sea area over the continental shelf to be explored satisfactorily between Kakinada in the south and False Point in the north, yet our investigations have indicated 4 chief trawling and gill netting grounds or areas, in depths chiefly between 15 and 80 metres off-shore. These are the sea areas boxed between :

(*a*) 17° 40′ N and 18° 10′ N and 83° 30′ E and 84° 20′ E; off Vizagapatnam and Bimlipatnam. The bulk of the catches here consisted of *Upeneus*, *Saurida*, *Johnius* and other small fish. A few large sharks and prawns (specially at night) were taken here.

TABLE VII

Vessel	Areas fished	Depth (M)	Gear used	Number of				Average catch per			Total catch	Amount
				Voyages	Days	Hauls	Hours	Day	Haul	Hour		
												Rs. nP.
Ashok ..	Vizag-Paradwip	22–120	Otter Trawl. Hoover, Grimsby, Murmansk	42	92	235	729	831·4	326	105	76,496	22,428 37
Gudjon ..	Vizag coast	22–80	Longline and Otter Trawl, Murmansk	75	75	127	233	314·4	186	101	23,582	11,968 12
Sea House ..	Vizag and Paradwip	14–80	Otter Trawl. Shrimp, Murmansk	85	88	229	292	172·3	66	52	15,162	4,453 12
Sagar Kumari ..	do.	14–80	Driftnets and Otter Trawl, Shrimp, Murmansk	150	150	282	537	119·1	63	33	17,864	7,675 25
Dan Boat I ..	Vizag	14–40	Bottomset Nylon, Gill nets	127	127	86	1270	59·7	88	6	7,585	4,299 50
Dan Boat II ..	do.	14–40	do.	100	100	68	1000	55·7	82	6	5,665	3,292 00
Total ..	..	..	..	579	632	1027	4161	231·5	143	33	1,46,354	54,216 36

(*b*) 18° 30′ N and 19° N and 84° 30′ E and 85° E; off Kalingapatnam and Baruva. This area is very prolific in large sciaenids, *Priacanthus* and carangids in day hauls; and in prawns during night time. Catches of 600 kg./hour and over were not uncommon.

(*c*) 19° 20′ N and 19° 50′ N and 85° 30′ E and 86° 20′ E; off Chilka, Puri and River Devi. The catches here contained a greater proportion of pomfrets, sharks and prawns. The prawns occurred chiefly during night hauls.

(*d*) 20° N and 20° 30′ N and 86° 40′ E and 87° 30′ E; off the mouth of the river Mahanadi. This area is rich in medium and small size prawns, juvenile pomfrets, sciaenids, clupeids and carangids. The prawns appear to inhabit the shallows inshore.

All the grounds above yielded over 100 kg./hour of trawling. Chief species identified in the catches are shown in Table VIII with their individual contributions.

During the year under review M.T. *Ashok* undertook seven voyages for exploratory trawling in persuance of F.A.O.'s programme, in the regions between Visakhapatnam and False Point and yielded on an average 96·78 kg. per hour of trawling. This area for convenience was divided broadly into four zones, *viz.*, (1) Zone A: Visakhapatnam to Kalingapatnam; (2) Zone B: Kalingapatnam to Gopalpur; (3) Zone C: Gopalpur to Puri and (4) Zone D: Puri to False Point. The entire area was further subdivided into squares each square measuring 10×10 miles and numbered. Each zone was thus approximately made up of 15–17 squares. Although there were about 60 squares in the entire area between Visakhapatnam and False Point trawling operations were restricted to only 29 squares and they were square Nos. 19, 22, 23, 24, 27, 28, 36, 37, 39, 40, 42 A, 56, 57, 58, 59, 63, 68, 69, 69 A, 70, 71, 72, 72 A, 72 B, 73, 73 A, 74 and 75. Further major fishing was done in depths ranging from 0 to 30 fathoms. Fishing in depths beyond 30 fathoms was not uncommon though not as extensive as in lesser depths. The yield per hour of fishing in each square ranged from 13·33 to 606·55 kg., the maximum yield being in square No. 42 A and the minimum in square No. 24. While 7 squares, *viz.*, square Nos. 24, 29, 40, 56, 57, 68 and 69 A yielded 0–50 kg. per hour; square Nos. 22, 23, 27, 59, 63, 71, 72, 72 B, 73 A and 74 yielded 50–100 kg. per hour, square Nos. 28, 36, 70, 73 and 75 yielded 100–150 kg. per hour, square Nos. 19, 72 A yielded 150–200 kg. per hour and the yield in square Nos. 37, 39, 42 A, 58 and 69 was above 200 kg. per hour. Accordingly zones A, B, C and D respectively yielded 75.

TABLE VIII

	Species	Ashok	Gudjon	Sea Horse	Sagar Kumari	Dan Boat I	Dan Boat II	Dan Boat Total
1.	Crabs (*Neptunus* Charybdys)	163	263	141	45	.	5	617
2.	Prawns (*Fenaeus*, *Metapenaeus*)	3,320	777	452	836	.	..	5,385
3.	Skates	3,123	401	218	180	105	13	4,040
4.	Rays	3,758	448	1,400	537	..	3	6,146
5.	Sharks ..	6,296	469	329	1,115	6,404	4,524	19,137
6.	Saw fish ..	3,643	86	460	280	573	410	5,452
7.	Eels ..	2,569	99	43	96	..	.	2,807
8.	Cat-fish ...	14,316	1,227	981	781	268	409	17,985
9.	Podimeen (misc.)	34,163	15,178	10,590	11,354	10	28	71,323
10.	Small sciaenids	..	1,242	..	430	..	.	1,672
11.	*Chorinemus* ..	.	..	..	..	18	71	89
12.	Seerfish .	7	.	..	..	65	69	141
13.	*Chirocentrus* ..	161	..	.	17	51	27	256
14.	Karkara ..	2,647	267	65	58	8	..	3,045
15.	*Drepane* ..	314	93	66	50	..	..	523
16.	*Trichiurus* ..	23	2,681	43	67	..	..	2,814
17.	Pomfrets ..	216	88	96	10	..	..	410
18.	Soles ..	137	35	4	36	..	..	212
19.	Silver bellies .. (large)	..	.	85	..	..	..	85
20.	*Lactarius* .	15	..	..	..	..	..	15
21.	*Polynemus* ..	4	.	.	..	..	..	4
22.	*Upeneus* ..	93	..	..	100	..	..	193
23.	*Otolithus* ..	..	..	..	15	..	..	15
24.	*Hilsa* ..	..	.	..	..	12	10	22
25.	*Pellona* .	..	..	.	.	15	6	21
26.	Ghol .	387	85	60	39	56	67	694
27.	*Caranx* .	1,170	18	129	..	..	..	1,317
28.	*Lutjanus* ..	71	..	..	.	..	13	84
29.	Thom ..	.	20	..	..	..	..	20
30.	Jewfish .	..	..	..	1,820	..	.	1,820
	TOTAL ..	76,496	23,582	15,162	17,864	7,585	5,665	1,46,354

372, 48 and 96 kg. per hour. These exploratory trawling operations have shown that the grounds off Baruva support comparatively rich fisheries.

The yield per hour of fishing in depths ranging from 0 to 10 fathoms was comparatively higher than rise in depths up to 10–20 and 20–30 fathoms, the respective yield which was the maximum in depths ranging from 30 to 40 fathoms, because poorer in depths ranging either from 40 to 50 or from 80 to 90 fathoms, where the respective yields were 204·22, 198·34 and 22·67 kg. per hour. It may therefore be of interest to work here that maximum yields were met with once in depths ranging from 0 to 10 fathoms and a second time in 30 to 40 fathoms. The other regions so far fished were comparatively lesser in yield.

About 4,000 specimens of fish representing 68 samples and belonging to 77 families, 119 genera and 167 species were examined at the laboratory for recording the three lengths, the sex, the weight, the fulness of stomach and the stage of maturity of each specimen. Based on this data studies on length frequency, minimum size at first maturity with respect to sex and the feeding intensity in relation to size were completed for the following in relatively important species, *Upeneus sulphureus*, *Nemipterus japonicus*, *Saurida tumbil*, *Pseudarius jella*, *Euplatygaster indica*, *Uranoscopus juscomaculatus*, *Pomadasys argyreus*, *Cynoglossus macrolepidotus*, *Scoliodon sorrakowah*, *Johnius aneus*, *Parastromateus argenteus* and *Anchoviella insularis*. The mean lengths of the above 12 species respectively were $10{\cdot}08 \pm 0{\cdot}06$; $10{\cdot}07 \pm 0{\cdot}29$; $13{\cdot}82 \pm 0{\cdot}29$; $25{\cdot}08 \pm 0{\cdot}65$; $20{\cdot}44 \pm 0{\cdot}27$; $9{\cdot}99 \pm 0{\cdot}14$; $12{\cdot}46 \pm 0{\cdot}16$; $16{\cdot}15 \pm 0{\cdot}39$; $35{\cdot}40 \pm 0{\cdot}04$; $15{\cdot}44 \pm 0{\cdot}13$; $18{\cdot}09 \pm 0{\cdot}15$; $5{\cdot}92 \pm 0{\cdot}04$ cm. Their sex ratio was also studied. The length-weight relationship of the following 5 species only was computed. *P. jella*, *J. aneus*, *U. sulphureus*, *U. juscomaculatus* and *S. tumbil*. Similar studies on the following species, which were also of equal importance by numbers in the catches, were taken up in the last quarter and are in progress: *Polynemus sextarius*, *Apogon septemstriatus*, *Grammoplites scaber*, *Callionymus sagitta*, *Lactarius lactarius*, *Leiognathus hindus*, *Pentaprion longimathus*, *Secuter ruconius* and *Drepane punctata*.

(*f*) *At Calcutta*

Twenty-three voyages were made by the West Bengal fisheries trawlers during the period under report. Out of the five deep-sea fishing trawlers (Kalyani I–V), Kalyani I, had not undertaken any voyage due to major-engine trouble during this year. Kalyani II made only one voyage, Kalyani III performed seven voyages, Kalyani IV six voyages and Kalyani V nine voyages.

TABLE IX

Name of the fishes	Total weight in kg.
"A" Class:	
Pampus argenteus ..	7,611·83
Penaeus spp. ..	1,211·58
Pomadasys hasta ..	3,073·25
Lutjanus spp. ..	34·40
Otolithus spp.	24·00
Pseudosciaena diacanthus ..	31·70
Scomberomorus spp. ..	16·83
Drepane punctata ..	4·70
TOTAL ..	12,008·29
"B" Class:	
Sciaenids ..	59,735·34
Leiognathus spp. ..	34,837·05
Kurtus indicus ..	11,637·16
Pellona spp. ..	14,041·73
Reconda russeliana ..	1,222·09
Opisthopterus tardoore ..	314·90
Engraulis spp. ..	803·19
Upeneus indicus ..	3,010·46
Polynemius sextarius ..	469·88
Lactarius lactarius ..	998·47
Small perches (*Pomadasys*, *Therapon* and *Nemipterus*)	1,160·07
Caranx spp. ..	2,359·40
Small prawns (*Metapenaeus*) ..	227·00
Acetes sp. (Shrimps) ..	75·00
Muraenesox ..	2,315·35
Arius spp. (big) ..	723·80
Drepane punctata (small) ..	78·90
Coilia spp. ..	6·50
Dussumieria acuta ..	129·70
Miscellaneous ..	8,859·77
TOTAL ..	143,003·76
"C" Class:	
Arius spp.	1,215·50
Skates ..	294·00
Saw fish (*Pristis* spp.) ..	118·00
Rays ..	3,423·08
Miscellaneous ..	590·26
TOTAL .	5,640·84
GRAND TOTAL ..	160,652·89

Among the total catch of 1,60,652·89 kg., " A " class fish were represented by 12,008·29 kg., " B " class by 14,3003·76 kg. and " C " class by 5,640·84 kg. The details of the catch composition of the different species of fishes landed during this year under review are given below (Table IX).

The deep-sea fishing activities of the West Bengal fisheries trawlers Kalyani II–V started by the middle of September, May–August being the monsoon months. The fishing operations were confined to off Matla estuary Western Channel, Eastern Channel, Mahanadi River, Devi and Chilka at a depth ranging from 7 to 25 fathoms. The fishing was concentrated more towards off Mahanadi River mouth during the year. It is obvious from the catch analyses (*vide* Table X) of the different fishing regions that *Sciaena* spp., *Kurtus indicus*, *Harpodon nehereus* and *Upeneus indicus* occur in large quantities in Sand head off Devi and Prachi Rivers and off Mahanadi. *Pampus argenteus* appears in abundance at off Mahanadi and Black Pagoda. The major catches in False Bay are clupeoids.

TABLE X

S. No.	Name of fish	Total yield in kg.	Area of abundance
1	*Pampus argenteus* ..	7,611·83	Off Mahanadi, Black Pagoda
2	*Sciaena glaucus* .	31062·00	Devi and Off Prachi and Off Mahanadi
3	*S. aneus* ..	8960·00	Sand Heads
4	*S. carutta* ..	11947·00	Off Mahanadi
5	*Sciaenoides microdon* ..	597·00	Black Pagoda
6	*Kurtus indicus* .	11637·16	Devi and Prachi, S. Heads and Off Mahanadi
7	*Pellona indica* ..	14041·73	False Bay
8	*Harpodon nehereus* ..	..	Devi and Prachi
9	*Upeneus indicus* ..	3010·46	Devi and Prachi

The quantity of marine fish landed by the fisheries trawlers during this year was 1,60,652·89 kg. of which " A " class were represented by 12,008·29 kg., " B "" class by 1,43,003·76 kg. and " C " class 5,640·84 kg.

Pampus argenteus formed the main bulk of the " A " class category. The other two varieties of pomfrets are *Parastromateus niger* and *Pampus chinensis* which formed negligible quantities.

A comparative analysis of the catch during this year and the previous one (*vide* Table XI) revealed that there is a considerable decrease in the total catch as well as the average catch during the year. It is also observed that there is a considerable increase in the catch of " A " class catch from 3% to 7·47% and decrease in " B " and " C " catches, from Table XI represents a comparative account of the catch, etc., during the year ending 31st March 960 and 1961.

TABLE XI

Period	Total No. of voyages made	Catch by class in kg.			Total catch in kg.	Catch per voyage
		A	B	C		
Year ending 31–3–1960	25	7,218·70	2,22,921·75	7,578·85	2,37,719·30	9,708·77
Year ending 31–3–1961	23	12,008·29	1,43,003·76	5,640·84	1,60,652·89	6,984·91

Though there is a sudden decrease in the landings from 63 to 37·18% of " Bhola " fishery when compared with the previous year, the sciaenids continued to be the major fishery of the coast. A peak period in the abundance of sciaenid fishery is noted in the month of February. The dominant species in the catch were *Sciaena glacus* and *S. aneus* contributed 48·4% and 22·8% respectively. A significant increase in the landing of Silver bellies was observed and formed 21·68% of the total catch. A failure in glass fish (*Kurtus indicus*) was noted which was represented by 7·24% as against in the previous year. Clupeoids constituted 8·74% and were dominated by *Pellona indica*, *Reconda russeliana* and *Opisthopterus tardoore*, Pomfrets, and prawns formed a negligible quantity of the catch and formed 4·74% and 0·75% respectively.

It is evident from Table XI that there was a progressive increase in the production of marine catch with the approach of winter season. December, January and February were the most productive periods with a peak in the month of February. During these three months 107,459·44 kg. were

obtained which formed 66·8% of the total catch of the year. It is also to be noted that of the total catch of 160,652·89 kg. for the year, 100,555·77 kg. were caught from off Mahanadi. Out of the above 100,555·79 kg. 9987·15 kg. were represented by " A " class category which indicates the quality fishing ground. It was also noted that between 8 and 20 fathoms the catch was more abundant.

Studies have been initiated on the biology of *Pampus argenteus*, *Kurtus indicus* and *Sciaena glacus*.

Studies on the food and feeding habits of other sciaenids which occur in sufficient quantities in the West Bengal trawlers catches are receiving attention.

C. Marine Fish Culture and Physiology

A tendency for a fall in fish production in the marine fish ponds, as compared to the previous years, was reported earlier. The results of experiments during 1960–61 confirm this experience. The maximum yield in the ponds this year has been only of the order of 100 pounds of fish per acre whereas previously the production has varied from 190 to 405 lb. per acre.

An experiment was tried by doubling the rate of stocking to 10,000 fingerlings per acre in some of the ponds. By regular weeding of the predators and safeguarding the sluices during water flow, a nearly 70% of survival of fish (unlike about 30% in previous years) has been possible. But such a high rate of stocking and increase in survival rate has apparently resulted in a poor growth of the fish over a ten months period. These fingerlings of 80 mm. in length at the time of stocking had grown over this period only to a length of 160–240 mm. whereas in previous experiments with only half the rate of stocking the growth had been nearly double, indicating thereby that these ponds may not be able to support such a high number of fish per unit surface, unless other measures for improving the fertility are taken.

Prolonging the growth of the fish for a period beyond one year in the present ponds under existing conditions also does not seem advantageous. Experiments carried out in this direction show that *Chanos* left over for the second year had not progressed significantly in their individual length or weight and it might appear more profitable to have the harvests from these ponds made at the end of every year and the ponds restocked. Perhaps the experiments should be attempted when more number of larger rearing ponds are constructed.

The various experiments and observations conducted during this year have helped to throw some light on the more probable causes for the continued reduction in fish yield year after year, and for the better management of the ponds in future. Added to the natural low productive potential of the area there is a depletion in the available fish food in these ponds during the successive years. The normal growth of microflora and other fish food is inadequate to cope with the continued deficiency. The standing crop of planktonic elements has been uniformly low in all the ponds throughout the year. The little improvement being brought about by repeated replenishment of water from the sea, addition of organic manures or even supplementary feeds such as oil-cake and rice bran has been found insufficient, especially for the growth of the larger fish. Thus the result at the end is a uniform retardation in the growth of the fish. Another problem that has arisen recently is the growth in certain ponds of a sea grass. Being the only vegetation in the pond and suspected to be beneficial, no attempt was made to eradicate this sea grass in its initial stages of growth. However, this weed has established itself well and has been growing luxuriantly at the expense of the little nutrients that are available in the ponds and this might be pointed out as another factor responsible for retarding the growth of the fish in such of those ponds where the weed has been present. It has since been observed that the milkfish does not make use of this sea grass which has a tough type of cellulose and as such has been found to be harmful in *Chanos* ponds. Means of eradicating this weed are now under contemplation.

For a proper understanding of the deficiencies and possible means of improving the conditions of the ponds for promoting better growth of fish, chemical analyses of the pond water and mud have just been started.

Physiology

The following projects were undertaken by the beginning of the year 1961.

(1) A study on conditioned responses in the fingerlings of *Chanos chanos*,

(2) Rate of filtration in *Meretrix meretrix*,

(3) A study of the metabolism in *Mugil* spp.

Conditioned responses are being studied in the fingerlings of *Chanos chanos*. Several experiments were designed and carried out to study the intensity of olfaction and vision in locating food. Experiments are in progress for conditioning fishes to olfactory stimuli.

Cole's neutral red technique for the estimation of filtration rate is greatly modified to suit the work of *Meretrix meretrix*. The filtration rate is being studied in different size-groups of this clam.

Standardization of the methods for the study of oxygen consumption and metabolism is completed.

IV. Marine Biology

A. Planktological Investigations

(*a*) *At Kandla*

Plankton studies in general confirm the previous year's results. Zooplankton constitute the bulk of collections, most common forms being *Acartia*, *Labidocera*, *Centropages*, *Eucalanus*, Pseudodiaptomids, *Rhincalanus*, *Euterpina*, *Oithona*, *Coryceaus*, crustacean eggs and larvae, and bivalves, gastropods, echinoderms and polychaet larvae. Fish eggs and larvae were observed in August to November and again from February to March. Chaetognaths appeared in moderate numbers during November to March.

(*b*) *At Karwar*

This year the maximum phytoplankton was recorded in the pre-monsoon months. Towards the south there was a secondary peak in the month of October. During January to March phytoplankton occurred in plenty. *Chaetoceros* spp. was the most common form present. *Thalassiothrix frauenfeldii* and *Nitzchia seriata* played the major role in some collections. *Fragilaria oceanica* appeared in fairly good numbers in the south. Monsoon blooms of diatoms were absent here this year also. *Coscinodiscus jonesianus* was present almost all through the year. *Coscinodiscus* sp., *C. asteromphalus* and *C. gigas* were found in plenty during January to March. *Hemidiscus hardmannianus* was present in Karwar and Chendia in May-June. *Trichodesmium* was found to occur all through the first quarter of the year and in some collections it dominated over the diatoms. It was abundant along this coast in the first half of June and at some places in the last quarter of the year also.

In April, May and June a good number of dinoflagellates occurred with *Ceratium trichoceros* as the dominant species. In October dinoflagellates attained the peak at all centres, with *Ceratium vultur* (forming colonies) as the important item. Chendia was exceptionally rich. *Ceratium furca*, *C. fusus* and *C. tripos* were abundant in some collections. From November onwards dinoflagellates were rare.

Noctiluca miliaris was more common in the post-monsoon period this year except in Kumta but was never found to discolour the water. Various planktonic larvae were abundant in October to March. They were comparatively rich this year. Copepod nauplii were common in October and crab larvae were numerous in January to March. Appendicularians which were abundant in the north were found decreasing towards the south. Cladocerans occurred in September to March with October as the peak. *Evadne tergestina* was more common up to September in Chendia and Kumta, and up to October at Karwar and Ankola. Later *Penilia avirostris* dominated. Copepods were abundant during September to December. *Acrocalanus longicornis* was abundant in the north. At Kumta *Acartia erythraea* dominated. *Oithona oculata*, *Schmackeria serricaudata* and *Temora turbinata* appeared in good numbers in the peak period. Chaetognaths when compared to that of the previous year were less. Fish eggs and larvae were generally few and they occurred at all places after the monsoon only. Carangid and clupeoid eggs and larvae were found frequently. Eggs and larvae of *Sardinella fimbriata* and Anchovy were found. Larvae of *Chirocentrus* occurred at Kumta in May to June. Larvae of *Cynoglossus* sp. were found at all places in the first quarter of the year. Leptocephalus and post-larva of eel were found in Kumta in the month of April.

(*c*) *At Mangalore*

Regular collections were interrupted during the south-west monsoon due to rough sea. Rest of the period regular weekly collections were made at the four fathom area at Ullal. The displacement volumes of plankton (surface hauls) were high in June due to phytoplankton bloom and in August due to swarming of *Noctiluca*. From October to March the plankton was fairly rich both in quantity and quality but during April and May it was poor.

In April a bloom of *Hemidiscus* sp. and *Trichodesmium* sp. was observed. *Trichodesmium* sp. continued to form the bulk of the plankton along with *Coscinodiscus*, *Chaetoceros*, *Rhizosolenia* and *Biddulphia* in the subsequent month also. In early June species of *Coscinodiscus* and *Thalassiothrix* were observed in good numbers, whereas *Schrodrella* sp., *Eucampia* sp., *Biddulphia*, and *Fragilaria oceanica* relatively few. In the last week of August a bloom of *Coscinodiscus* sp. and *Noctiluca* sp. was observed. Post-monsoon phytoplankton bloom was noticed in October, and the important diatoms were species of *Chaetoceros*, *Coscinodiscus*, and *Fragilaria oceanica*. In November, same species of diatoms were noticed but in lesser numbers. In December, there was a minor bloom of dinoflagellates, *viz.*, *Ceratium trichoceros*,

C. massiliensis and *C. fusus*. In January and February, the phytoplanktonic elements were rather poorly represented. In the latter half of March, bloom of *Bellarochea malleus* and *Pleurosigma* sp., was observed at Ullal.

During June, July and August the plankton was composed mainly of phytoplankton elements. From September onwards, zooplankton showed increase in quantity. Cladocerans and copepods were dominant, the first group during September to October and the second from November to March. A swarm of fish eggs (clupeoid type) was observed in March. During May *Lucifer* were dominant. Larval bivalves and gastropods, larval polychaetes, penaeid and brachyuran zoea, hydromedusae, ctenophores, *Sagitta*, pteropods, *Oikopleura* and Cirriped nauplii occurred in small numbers in the plankton. No exclusive swarms of any group of animals was observed during the year. In the last week of August *Noctiluca* swarmed and the swarm persisted up to early September discolouring the water slightly.

(*d*) *At Kozhikode*

During the year, studies were conducted on the magnitude of the standing crop of phytoplankton by the net collections and on organic production by the 'dark' and 'clear' bottle experiments.

The standing crop in general was poorer than the preceding year both by volume and pigment and the poorest period was November to January. The seasonal cycle of phytoplankton was of the same pattern as the previous years, with a short bloom of moderate intensity during the south-west monsoon attaining its peak in June by pigment and August by volume and an almost negligible secondary peak during February to March. The occurrence of *Fragilaria oceanica* was not at all sustained one, although abounding in a few collections after the primary bloom. Swarms of *Trichodesmium* bundles were in plenty during the hotter months.

In the pre-monsoon period and again from October onwards copepods formed the most significant group of the zooplankton, the commonest available being species of *Labidocera*, *Paracalanus*, *Acrocalanus*, *Acartia*, *Eucalanus*, *Undinula*, *Centropages*, *Temora*, *Pseudodiaptomus* and *Corycaeus*. Both the cladocerans, *Evadne* and *Penilia* had their own periods of dominance, the former in August-September and the latter in October-November. By December both had dwindled and were no more than barely represented; but they continued to be available, though in sparse numbers all through the year. Siphonophores, medusae and salps were abundant in November–February. Medusae and salps in particular came in unusual abundance in

the inshore waters in November–December. Penaeid and Sergestid larvae showed their usual abundance in December–March. Others of good but restricted occurrence during the post-monsoon months were the pteropods ostracods, *Lucifer*, *Sagitta* and appendicularians. *Noctiluca miliaris* was represented throughout the monsoon season but not in such abundance as to discolour the water, which phenomena was only very rarely observed this year. A few *Noctiluca* swarms were seen to voraciously feed on plankton organisms and thus to multiply vigorously. Fish eggs and larvae were chiefly available in September–November.

During the year under report observations on bottom fauna and bottom plankton were carried out at Vellayil also in addition to West Hill.

Green mud, abundant with foraminiferan shells, was washed ashore during April–May. The mud-bank thus formed lay exposed to over a distance of half a mile into the sea during low tide, and was subsequently washed away from the shore by the south-west monsoon. Bottom plankton of the post-monsoonic season was abundant with planulae, viligers, trochophores, young *Prionospio pinnata* and Polynoid larvae, but the bottom mud was not successfully colonised by the adults of these (with the possible exception of actinarians which settled during November). Particularly conspicuous was *P. pinnata*, which was never found in abundance this year, whereas during the post-monsoonic months of 1959, the 2 and 4 fathom areas were dominated by young ones of these. Same size-groups, or even smaller size-groups, of *P. pinnata* have been observed in but small numbers in successive weekly samples this time, suggesting that the larvae have been trying to settle down from time to time, but not with much success. The removal of the mud-deposits by the monsoonic weather and the resultant depletion of the nutrient content of the bottom mud seem to have played a significant role in delaying the metamorphoses of the larvae invertebrates of this area. Owing, perhaps, to the non-availability of mud-living animals during the third quarter, *Cynoglossus semifasciatus*, Sciaenids and prawns were found to be feeding, not on animals that live in the mud, but on those forms that inhabit the bottom layers of water. The bottom fauna has been poor throughout the last quarter also. *Phyllochaetopterus socialis* was abundant on 28–3–1961 at 8 fathoms.

(*e*) *At Cannanore*

Studies on the seasonal fluctuation of the plankton of the Cannanore Bay from two stations (3 F and 6 F) were commenced from the post-monsoon season of the year under review. Such " edible " planktonic elements as

copepods, dinophysids, cladocerans and larval decapods reappeared in the latter half of the third quarter and continued to dominate the plankton till the end of the year. There was a minor peak of diatoms during December and January. *Noctiluca* reappeared in February, and continued to be dominant in March also, but the occurrence of " red water " due to swarming of pink *Noctiluca* was observed only in November. Towards the close of the year more and more off-shore planktonic elements, such as salps, certain medusae, doliolids, rare chaetognaths and pelagic molluscs started appearing. Prawn eggs and larvae were dominant during November and December. Eggs of *Sardinella fimbriata* appeared in November. The displacement volume increased steadily towards the close of the year due to occurrence in large numbers of macroplanktonic elements.

(*f*) *At Tuticorin*

The phytoplankton generally remained poor. However during the month of May 1960 phytoplankton was well represented in the hauls with species of *Coscinodiscus*, *Thallasiosira*, *Thalassiothrix*, *Ditylum*, *Chaetoceros* and *Rhizosolenia*. A rich bloom of *Rhizosolenia* sp. occurred during the first week of September and during the last week of November there was a rich bloom of *Thalassiothrix* sp.

Observations on the zooplankton showed that copepods dominated in most of the samples with occasional abundance of chaetognaths, pteropods and cladocerans especially during the months of April, May and August and October. Among the copepods, various species *Eucalanus*, *Paracalanus*, *Canthocalanus*, *Calanopia*, *Canadacia*, *Centropages*, *Acartia*, *Corycaeus* and *Oithona* were commonly represented. Other organisms that were regularly occurring were *Lucifer* spp., crustacean larvae and *Oikopleura*. *Noctiluca* swarmed during the second week of September and the second week of October.

(*g*) *At Mandapam*

Planktological investigations in the inshore waters of the Gulf of Mannar and Palk Bay showed that the summer bloom started in Palk Bay early in May with *Chaetoceros* spp. and *Thallasiothrix frauenfeldii* as dominant species. Later on *Bacteriastrum hyalinum* bloomed and continued to be the dominant species up the middle of June when species of *Chaetoceros* again dominated. Species of *Rhizosolenia* were common from the end of May to the end of June. In the Gulf of Mannar zooplanktonic elements dominated in April–May but by the end of May the summer started with *Coscinodiscus* spp. and *Chaetoceros* spp. The summer bloom continued practically up the third

week of October in Palk Bay, while it lasted only till the middle of August in the Gulf of Mannar. *Ceratium massiliense* appeared in appreciable numbers in the Gulf of Mannar towards the end of April and they bloomed in Palk Bay during the middle of July. During October–November and the third week of December phytoplankters showed a marked increase in the Gulf of Mannar. This increase in November–December is somewhat unusual for the period because in previous years phytoplankters were extremely low during these two months.

Studies on organic productivity by the oxygen method was continued from six stations in the Gulf of Mannar. More than three years' data from the original station and two years' data from the other five stations have been so far collected. A set of experiments was conducted off Tuticorin at 15 metres. With these data the total annual production of carbon for the inshore waters of Gulf of Mannar from Cape Comorin to Dhanushkodi was estimated. An appraisal of fish landings of this zone in terms of carbon present yield is only 1/7 to 1/12 of a possible exploitable stock. Similar studies were extended to Palk Bay from May 1960 but only six months' data could so far be collected as observations could not be conducted during rough weather. Observations are being made from three stations at 2, 4, and 6 fathoms which besides oxygen experiments include pigments, phosphate and nitrate. In order to check the values of oxygen experiments, few ^{14}C experiments also were conducted.

(*h*) *At Madras*

Plankton samples obtained by using different types of net were under study and all relevant data—pigment value, displacement volume, dry weight, etc.—have been recorded. The data show that in 1960–61 (April–March) the maxima for both phyto and zooplankton as well as macroplankton occurred in May, values showing a trend to rise from March and the period of minimum in December or January. From August to November the values did not show sharp fluctuations. Work is being continued.

B. Hydrological Studies

(*a*) *At Kandla*

Hydrological observations were made at Luni, Modhwa and Kandla. The fluctuations in pH, temperature, oxygen, phosphate, nitrite, silicate and salinity were as follows:

Monthly average value :

Luni centre.—At Luni centre the mean monthly values of pH ranged from 8·1 in January and February 1961 to 8·45 in December 1960. Temperature was lowest in January with 17·5° C. and highest in October with 26·5° C. The oxygen concentration for the same period varied from 4·962 c.c./l. in October 1960 to 6·198 c.c./l. in January 1961. The highest concentration of phosphates was noted in December with an average value of 0·689 μg.at./l. while the lowest in January was 0·198 μg.at./l. Nitrite values were at the minimum in November with a reading of 0·120 μg.at./l. and the maximum in October with a reading of 0·485 μg.at./l. Silicates too had the maximum in October with a concentration of 25·00 μg.at./l. but the minimum was in January with a concentration of 13·16 μg.at./l. The highest salinity was in February showing 42·54 ‰ and the lowest in October with 35·76‰.

Modhwa centre.—During the October 1960–January 1961 period pH ranged from 8·7 to 8·1, the highest being in January and the lowest in February. The surface temperature ranged from 19·4° C. to 19·8° C. during the latter three months whereas in October it was 27·0. The dissolved oxygen was lowest in October with a concentration of 3·882 c.c./l. and the highest in January with 6·503 c.c./l. Phosphates varied from 0·295 μg.at./l. in November to 0·923 μg.at./l. in January. Nitrite ranged from 0·050 μg.at./l. in December to 0·400 μg.at./l. in January. Silicate was highest in October with a concentration of 19·23 μg.at./l. and the lowest in December with 6·20 μg. at./l. The salinity ranged from 32·72‰ in November to 38·39‰ in January.

Kandla centre.—During the period of April 1960 to March 1961 the variations in pH were 8·10 in March to 8·50 in September. The lowest temperature of 17·72° C. was recorded in January and the highest 29·30° C. in July. Dissolved oxygen varied from 4·081 c.c./l. in August to 6·303 c.c./l. in January. Nitrite concentration was the lowest in September with 0·170 μg.at./l. and the highest in January with 0·459 μg.at./l. Silicate ranged from 26·73 μg.at./l. in September to 16·54 μg.at./l. in March. Phosphate concentration varied between 0·305 μg.at./l. in October and November 1·089 μg.at./l. in August. Salinity throughout was high ranging between 36·44‰ in May and 40·57‰ in June.

(*b*) *At Karwar*

As in the previous year surface temperature was generally high in the beginning of the year. During the rainy season it decreased to the minimum.

But the minimum values for this year were higher than that of the minimum for the year 1959–60. In the post-monsoon period the temperature rose and after a slight fall in December it rose again to fall once more in February. In Chendia the temperature rose after the monsoon and registered the fall in February only. As in the previous year lowest record of temperature at Karwar was in August. At Chendia, Ankola and Kumta it was in September. pH and salinity were also low in the south-west monsoon period. Dissolved oxygen content was high during August. Phosphates remained low throughout, whereas nitrite was much higher this year, the peak being in May–June. Concentration of silicates, as in the previous year, was high in the north and low towards the south. But this year the maximum values for the silicates were only 37·65%, 42·66% and 65·66% at Karwar, Chendia and Ankola respectively of the maximum record of the year 1959–60.

(*c*) *At Mangalore*

Sea-water samples were collected once a week at the 4 fathom area of Ullal. On a few occasions collections could not be made due to inclement weather conditions.

The average surface temperature of sea-water for April and first half of May was 30·6° C. being the highest value, and this dropped to 28·4° C. towards the end of May. The average value for June was 27·2° C. and for August it was 23·4° C. In September temperature showed a gradual increase to 27·5° C. In early October the temperature value was 26·2° C. and in the subsequent month it was fluctuating between 28·8 and 29·2° C. In early December the temperature dropped to 26·9° C. and it was still lower (26·9° C.) towards the end of the month. There was not much variation in the temperature value for January. From February onwards a gradual increase in the surface temperature of sea-water was noticed; and in March it was fluctuating between 29·0 and 30·0° C.

(*d*) *At Ernakulam*

During the year under review the research vessel *Kalava* made seven cruises in all.

The summer conditions during the year 1960 were as follows:

In the early part of summer, a good isothermal layer with a thickness of nearly 85 meters was observed with a temperature range of 28·0–28·5° C. Later in the period a considerable degree of heating was in evidence, the temperature having risen up to 29·5–30·5° C. and the thermocline was seen to be present at about 90 meters,

In regard to salinity, although a gross examination reveals a more or less uniform surface salinity in the entire area a more detailed examination shows a decrease seawards. Nearer the shore the salinity range was 34·4–34·5‰ while beyond the shelf the waters had salinity values between 34·0 and 34·2‰. The obvious explanation is the greater degree of evaporation in shallow near shore waters. A well-defined salinity maximum is seen at about 100 meters. Below 200 meters the isohalines are nearly vertical showing good mixing at these levels.

The density surfaces down to 200 meters are practically horizontal indicating clearly the presence of a stable water column. There is a slight sloping of the surface below 200 meters, but whether it is any indication of water movements at these levels it is not possible to state with any degree of certainty.

The temperature-salinity relationships show the presence of three distinct sub-surface water masses observed during the same period last year. The surface water characteristics appear to extend down to 30 metres thus indicating a thick surface water mass.

Uniform and a high degree of oxygenation appears to be one of the main characteristics of the entire shelf waters at this time of the year. In the deeper waters beyond the shelf the high oxygen layer was seen to extend down to 50 metres and even more. Decrease was observed from 75 metres downwards and the oxygen minimum was reached between 150 and 200 metres. Even at 1,500 metres the value was less than 1 ml. per litre.

From a cursory examination of the data collected in the more recent cruises it is seen that the usual sinking phenomena was observed in January, the sinking being more prominent at the edge of continental shelf and along the continental slope. The northerly coastal drift was seen to be fairly intense. By February both the intensity of sinking as well as of the coastal stream has become considerably reduced.

Studies on the diurnal variations in the temperature-salinity characteristics of these waters at two selected stations—off Cochin and Calicut—reveal certain interesting features. From surface down to 30 metres the variations do not appear to be quite significant but become prominent from 50 metre downwards, more so below 75 metres. From the existing data mean values for these two parameters were calculated for various times of the day and the deviations from these means were obtained for the stations off Calicut and Cochin. In general the deviations were found to be more off Cochin than off Calicut. The maximum diurnal variation was observed at the

thermocline. This points to the existence of internal waves which probably have an amplitude of nearly 40 metres off Cochin and 20 metres off Calicut.

Hydrography of the Backwaters.—The main hydrographical conditions of the Cochin backwaters in the neighbourhood of the Willingdon Island were: a well-marked stratification during whole of September and up the third week of October; cold and heavy bottom water containing very little oxygen and overlying layer of warm, light and well-oxygenated water. The stratification began to disappear by the end of October and by December typical mixed conditions were observed. With the onset of summer, there is a great deal of warming up in the entire area.

(*e*) *At Calicut*

Studies on the seasonal changes in the hydrological factors of the inshore and off-shore waters of Calicut coast were continued. Off-shore collections were totally interrupted from May–November due to unfavourable weather conditions.

The temperature of the inshore and off-shore surface waters was highest in April with 30·7 and 30·4 while the lowest was 24·7 and 27·9° C. respectively. The lowest in inshore was in August and the off-shore in February.

The surface salinity in ‰ of the inshore area was highest in March (34·17) and lowest in June (29·15), while bottom salinity was highest in July (34·80) and the lowest in December (33·32). Surface and bottom salinities of the off-shore were highest in April (34·15 and 33·59) and the lowest in December (33·90 and 33·01) respectively. Oxygen of the inshore waters in c.c./l. at the surface and at the bottom was highest in February (4·68 and 4·82) and lowest in July (3·13 and 1·53). Surface oxygen of the off-shore waters was at a maximum in February (4·34) and minimum in April (3·88) while the bottom value was highest in March (5·02) and lowest in April (4·16).

Surface pH of the inshore region was maximum in April (8·7) and minimum in September (8·47), whereas at the bottom it was highest in February (8·6), and lowest in July (8·1). Surface pH of the off-shore waters was highest in April and December (8·7) and lowest in January (8·57) whereas the bottom pH was at maximum in February (8·65) and minimum in December (8·55).

Phosphates in μg.at./l. of the surface waters of the inshore area were highest in August (1·909) and lowest in December (0·276) while at the bottom phosphates were maximum in July (3·038) and minimum in February (0·431).

Surface phosphates of the off-shore area were highest in March (0·391) and lowest in April (0·308) while the bottom values were highest in March (0·721) and lowest in February (0·437).

Silicates in μg.at./l. of the inshore waters were highest in September (32·85) and lowest (4·00). Concentration at the bottom was at a maximum in August (35·65) and minimum in February (3·13). Surface silicates of the off-shore waters were at maximum in December (6·75) and minimum in January (5·08) whereas the bottom silicates were highest in December (9·13) and lowest in February (4·69).

Surface nitrites of the inshore area in μg.at./l. were highest in March (1·183) and lowest in April (0·033). Bottom values were at a maximum in December (1·763) and minimum in September (0·039). Surface nitrites of the off-shore area were highest in January (0·210) and lowest in April (0·028) and the bottom nitrites were at maximum in December (1·730) and minimum in February (0·318).

Surface total phosphorus of the inshore environment in μg.at./l. was having a peak value in September (7·093) and lowest in December (0·745). Total phosphorus at the bottom was at a maximum in September (8·307) and minimum in January (1·205). Surface total phosphorus of the off-shore waters was highest in April (1·952) and lowest in February (0·779) and the bottom phosphorus was at a maximum in April (1·852) and minimum in January (0·905).

(*f*) *At Cannanore*

Salinity and temperature reached higher values (30·2° C. and 36·1‰ respectively) during March, and except for a trough noticed during December, the values were steadily increasing from the second quarter of the period.

(*g*) *At Tuticorin*

During the months from May 1960 to August 1960 and from November 1960 to January 1961 the sea remained rough and turbid due to the activity of the monsoons.

The surface temperature fluctuated between 24·5 and 29·3° C. during this year. The low temperatures were noticed during November and December, whereas the maximum was in May.

The salinity varied from 34·05 to 36·6‰. Slight drop in the salinity was observed after heavy rains during the months of November 1960, and January 1961.

The pH ranged from 8·2 to 8·6.

The concentrations of inorganic phosphates were high during the months from May 1960 to September 1960 and comparatively low during the rest of the period. The range was from 10 to 33·3 mg. P./m.^{3}

The values for silicates fluctuated between 6·25 μg.at.Si/l. and 25 μg.at.Si/l. during this year.

The dissolved oxygen content ranged from 4·05 c.c./l. to 5·6 c.c./l.

CENTRAL MARINE FISHERIES
RESEARCH INSTITUTE,
Marine Fisheries P.O.,
Mandapam Camp, S. India,
March 31, 1961.

S. JONES,
Director.

V. LIST OF PUBLICATIONS DURING THE YEAR

1. GEORGE, P. C. AND ANNIGERI, G. G. 1960. On the occurrence of small-sized mackerels (*Rastrelliger canagurta* C.) off Ratnagiri coast. *Curr. Sci.*, **29**, 319–20.

2. JOB, S. V. 1960. Growth and calorific approximation in the Speckled Trout (*Salvelinus fontinalis*). *Indian J. Fish.*, **7** (1), 129–36.

3. JONES, S. 1960. Notes on eggs, larvae and juveniles of fishes from Indian Waters. V. *Euthynnus affinis* (Cantor). *Ibid.*, **7** (1), 101–06.

4. JAYARAMAN, R., RAMAMRITHAM, C. P., SUNDARARAMAN, K. V. AND ARVINDAKSHAN NAIR, C. P. 1960. Hydrography of the Laccadives Off-shore Waters. *J. Mar. Biol. Ass. India*, **2** (1), 24–34.

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9. KUNJU, M. M. 1960. On new records of five species of Penaeinae (*Decapoda macrura:* Penaeidae) on the West Coast of India. *Ibid.*, **2** (1), 82–84.

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12. ———— ———— ———— the leptocephali of Bombay Waters. II. The metamorphosing stages of *Muraenesox talabon* (Cantor). *Ibid.*, **52** (5) **B**, 169–81.

13. ———— ———— ———— the leptocephali of Bombay Waters. III. The metamorphosing stages *of Uroconger lepturus* (Richardson), *Ibid.*, **52** (5) **B**, 182–90.

14. ———— ———— ———— the leptocephali of Bombay Waters. IV. Some Ophichthyid Leptocephali. *Ibid.*, **52** (5) **B**, 191–208.

15. ———— ————. ———— the leptocephali of Bombay Waters. V. A few other leptocephali. *Ibid.*, **52** (5) **B**, 209–19.

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22. Raju, G. 1960. A case of hermaphroditism and some other gonadal abnormalities in the skipjack *Katsuwonus pelamis* (Linnaeus). *Ibid.*, **2** (1), 95–102.

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35. VIRABHADRA RAO, K. AND ALAGARSAMY, K. 1960. An account of the structure and early development of a new species of a nudibranchiate gastropod, *Eolidina* (*Eolidina*) *mannarensis*. *Ibid.*, **2** (1), 6–16.

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ANNUAL REPORT OF THE CENTRAL INLAND FISHERIES RESEARCH INSTITUTE, BARRACKPORE FOR THE YEAR 1960-61

General

Substantial progress was achieved during the year in all investigations undertaken by the Research Institute. There was also an all-round expansion of activities of the various sections and units, under both normal and Second Five-Year Plan programmes.

During the year under report, 6 additional residential quarters were constructed at Barrackpore at a cost of Rs. 1,22,200. An area of 35·25 acres of land was acquired for the establishment of an experimental fish farm in Kakdwip. The construction of Garage, Workshop and Stores at Headquarters was sanctioned at an estimated cost of Rs. 1,31,000. Sanction for the construction of an aquarium at a cost of Rs. 99,615 has also been received from the Government.

The draft proposals for the implementation of the Third Five-Year Plan programme were submitted to Government.

The following Officers were appointed during the year:

1.	Dr. Y. R. Tripathi	.. Research Officer (Sr. Grade)
2.	Dr. H. Chaudhuri	.. Research Officer
3.	Sri. V. R. Pantulu	.. Research Officer
4.	Sri. R. M. Bhowmick	.. Assistant Research Officer
5.	Sri. A. K. Basu	.. Assistant Research Officer
6.	Sri. Thomas Joseph	.. Administrative Officer

Dr. T. V. R. Pillay was relieved of his duties at this Institute on 14–4–1960 to take up the post of Deputy Director (Fisheries Extension) at the Ministry of Food and Agriculture on the recommendation of the Union Public Service Commission.

Training

The 13th Session of the Inland Fisheries Training Course commenced on 1st April 1960 at Barrackpore with a total of 28 trainees, comprising of

four Colombo Plan trainees under Technical Co-operation Scheme of the Government of India (one each from Philippines and Nepal and two from Malaya), sixteen State Government deputees and stipendiaries from Uttar Pradesh, Bombay, Madhya Pradesh, Punjab, Andhra Pradesh, Orissa, Assam, Tripura and Himachal Pradesh and eight private candidates from Madras, Uttar Pradesh, Madhya Pradesh, Bombay, Kerala, Bihar, West Bengal and Andhra Pradesh. At the final examination held in January 1961 one candidate was placed in the first class, 14 in the second class and 13 in the third class.

A Referesher Course for the Fishery Officers of the C.D. and N.E.S. Blocks was conducted under the joint auspices of the Fisheries Extension Units at Calcutta and Gauhati and this Research Institute. Shri H. Banerjee, I.C.S., Development Commissioner, West Bengal, inaugurated the course on 22nd September 1960. Lectures and demonstrations were given to the trainees at Barrackpore by different specialists.

Two Officers from Bombay Government Fisheries Department were deputed to this Institute for studying the techniques of induced breeding by pituitary gland injection.

A training course in deep water fishing in inland waters was conducted by this Institute at Maithon (West Bengal) from 15th to 30th October 1960, which was attended by 21 Officers from various States and Fisheries Extension Officers.

Meetings

The Director attended the meeting of the Fisheries Committee of the Tungabhadra Board on the 23rd and 24th November 1960 and participated in the Fisheries Research Committee meeting held at Puri on 13th and 14th December 1960. He represented the Government of India at the 9th Session of the Indo-Pacific Fisheries Council held at Karachi (Pakistan) in January 1961. The Director also attended meetings at the Ministry in April and June 1960 in connection with the finalization of the draft Third Five-Year Plan in so far as it related to the Fisheries Schemes.

F.A.O. Fellow

Miss M. Bryant, UNESCO Fellow from Liberia, visited this Institute during the year and arrangements were made for her training.

F.A.O. Expert

Mr. S. B. Gulbadamov, F.A.O. Gear Technologist, and the Russian Interpreter Mr. G. A. Semin continued to work at this Institute. After carrying out investigations in the Mettur Dam, Krishnarajasagar reservoirs and Damodar Valley Corporation reservoirs they left this Institute on 4th January 1961 after submitting their final report to Government. Dr. Y. R. Tripathi, Research Officer, continued to work as under study during the period the foreign expert was assigned to this Institute.

Evaluation Audit

Prof. H. S. Swingle, Rockefeller Foundation Expert, who was assigned to this Research Institute, reported here on 25th January 1961 and left for Delhi on 8th March 1961 on completion of the evaluation work and submitted his report to Government.

Miscellaneous

A representative collection of food fishes and a set of live fishes from the Central Inland Fisheries Research Institute and Molluscs from the Central Marine Fisheries Research Institute were presented by the Director to His Imperial Highness the Crown Prince of Japan on 8th December 1960 at Calcutta, on behalf of the Government of India.

Dr. H. Chaudhuri, Research Officer, was awarded "Chandrakala Hora Gold Medal" by the National Institute of Sciences of India for his outstanding contribution in the field of fish breeding.

Visitors

Shri T. S. Gill and Shri Sadanand of the Planning Commission, Shri V. V. Kalyani, Director of Fisheries, Mysore, Shri Krishan Chand, Joint Secretary, Dr. David D. Keck of the National Science Foundation, U.S.A., Dr. N. K. Panikkar, Fisheries Development Adviser, Dr. B. N. Chopra, Fisheries Consultant, National Council of Applied Economic Research, Dr. K. T. Jacob, Director, Jute Agricultural Research Institute, Mr. N. I. Borisov, Russian Expert in Marine Fisheries, Dr. T. R. Bhaskaran, All-India Institute of Hygiene and Public Health, Mr. Husanuddin Saanin, Head of Institute of Inland Fishery, Bogor, Mr. H. R. Mills, Director of Survey and Technical Training, Colombo Plan Bureau, Dr. P. V. R. Rao, Additional Secretary, Ministry of Community Development and Co-operation and a team of Officers, Mr. Wm. A. Dill, Chief, Inland Resources Section, Biology Branch of F.A.O., Rome, and Dr. Richard L. Weaver, Associate Prof. of

Conservation, University of Michigan, visited this Institute during the year under report.

Pond Culture Division

2. *Induced Breeding of Indian Carps*

Pituitary glands were regularly collected from mature specimens of Common carp and other fishes as and when they were taken out for marketing. Over 200 glands were collected from the Calcutta Fish Markets and over 1,000 glands from Gwalior also.

Regular fish breeding work taken up during June at the Pond Culture Research Unit, Joysagar, Assam, resulted in Catla, Rohu, Mrigal, Calbasu and Gonius breeding by hormone injections and producing approximately 10 lakhs of spawn. One large Catla, weighing 14·5 kg., was successfully induced to spawn by a single injection at 5 mg. of pituitary material per kg. body weight. About 20 lakhs of eggs were laid by the fish, 60% of which were fertilised. Two pairs of the catfish *Ompok bimaculatus* were also successfully induced to pawn by injections, producing over 24,000 hatchlings.

At Cuttack, experiments aimed at large-scale production of fish seed by injection of hormones were successfully carried out. At the beginning of the season (June), water conditions in ponds and channels were not very suitable for successful hatching of the eggs. These were overcome in July and successful spawning was obtained in 60% of the fishes (sets) injected. Of the successful cases, 40% responded to a single injection and 60% to two injections. The interval between first and second injections was generally 12 hours. The successful dose of injections were: single injection, 5–10 mg./kg. and 2 injections, 7·5–13 mg./kg. About 138 lakhs of spawn of major carps were produced by injections. A large number of these were lost by hapas getting submerged in the river or getting torn in ponds. However, 81·85 lakhs of spawn could be obtained for stocking.

Of all the major carps, Rohu predominated others, as the number of breeders was more. The stock of Catla breeders was not satisfactory. Only 9 female Catla were available for the breeding experiments. The maximum weight of Catla female was 5·5 kg. and it laid only about 5½ lakhs of eggs. The largest Rohu which bred successfully weighed 5·7 kg. and it laid nearly 10 lakhs of eggs, the percentage of good eggs being 95%. A female Mrigal weighing about 4·8 kg. laid 11·6 lakhs of eggs, of which over 90% hatched out.

Experiments were conducted for the standardisation of injection doses also. Records of the sex, length, weight and stage of maturity of donor fishes were always maintained. Individual glands were preserved and weighed separately. The doses were calculated in mg. weight of the gland per kg. of the body weight of the breeders. Although it is very difficult to determine the exact stage of maturity in a female fish from external characters, attempts were made to select good breeders by rounded bulging nature and softness of the abdomen.

A good number of Rohu-Calbasu hybrids were observed to have matured fully. One set of the hybrid (two males and one female) was injected with Rohu pituitary gland. One and a half lakhs of eggs were obtained after the second injection of the female. Sixty-five per cent of the eggs hatched out. 40,000 of the hybrid spawn were stocked in a nursery pond and a few thousands were reared in the laboratory. These hybrids show great variations in colouration of the body, fins, barbels and in caudal spots.

Pituitary glands of spent fishes (by injection) were also successfully used to induce spawning in other species. It is generally believed that with spawning the pituitary glands lose their hormone potency and hence glands from spent fishes are generally not collected for injection purposes. But in the present instance the donor fish itself spawned in response to heavy dose of extra hormones and not by the action of the hormones in its own pituitary gland.

Progeny of Mrigal and Calbasu produced in 1958 by induced breeding became mature by 1960 July and were successfully spawned by administering hormones. The young ones are being separately reared to find out how they will respond when mature.

The usual technique of injecting the male and female breeders simultaneously was slightly modified with advantage. The female alone was given a very low preparatory dose of hormones and 6--8 hours later, a higher dose was injected into the female and the normal dose to the males. The injected fish were then put together in the hapa and in majority of cases spawning took place within the next 3–6 hours.

Adequate stock of breeders of all major carps have been gathered and kept in selected ponds for experiments during the 1961 season.

3. *Breeding and Propagation of the Common Carp* Cyprinus carpio

The scale carp (var. *communis*) continued to breed throughout the year. As there was demand for spawn during the monsoon season for mixed

stocking with Indian carps, breeding on a limited scale was carried out during July–August also. The total quantity of spawn produced during the year amounted to 72,12,000, out of which approximately 62 lakhs were supplied to the Orissa State Fisheries Department.

In some of the breeding experiments, Kakabans made of Screw pine leaves and coconut fibre were repeatedly tried. Fishes spawned on the Kakabans and the eggs were sprayed on the upper surface only. Hatching of eggs, however, was poor as compared to eggs laid on weeds.

Detailed work on selective breeding of the coloured specimens was taken up. When the male and female parents were coloured the young ones were also found coloured, though showing wide colour variations. The young ones so produced are being separately grown, so as to stabilise desirable colours and combinations of colours.

It is commonly observed that among the brood of *Cyprinus* fry, a few grow much more rapidly than others in the same pond. With a view to find out how this occurs, detailed studies on the size of eggs and hatchlings of fishes of different sizes, the size of eggs and hatchlings from lots laid at different times during spawning and hatchlings obtained at different hours from the same brood, were made. A short-term study of the relative growth of selected fast-growing specimens from one brood and slow-growing specimens from another (both of comparable length and weight) indicated that the fast-growing ones are capable of better growth than the others.

During the period under report, fry and fingerlings of Common carp were supplied to the following agencies:—

Department of Fisheries, Orissa	..	2,71,608
Department of Fisheries, Punjab	..	12,880
Department of Fisheries, Mysore	..	5,000
Department of Fisheries, Pondicherry	..	5,000
Department of Fisheries, West Bengal	..	33,798
Department of Fisheries, Assam	..	8,000
Tungabhadra Board, Hospet	..	5,000
Fisheries Extension Unit, Calcutta	..	1,300
Central Inland Fisheries Research Institute, Barrackpore	..	500
Private Parties	..	4,000

4. *Observations on the Mirror Carp* (Cyprinus carpio *var.* specularis)

During the year under report, mirror carps spawned twice. About 25,000 spawn obtained from the second fish have been reared in a nursery pond and about 5,000 advanced fry, 1–1½″ long, were transferred to a rearing pond. They have now attained fingerling size and are to be distributed in stocking ponds.

5. *Observations on Chinese Carps*

Preliminary experiments using Grass carps (*Ctenopharyngodon idellus*) to control natural growth of submerged weeds in nursery ponds have been encouraging. A pond (0·1 acre) fairly choked with *Hydrilla* could be completely cleared by 15 Grass carps, each weighing about 0·226 kg. only, in the course of one month. At the rate of 50 per acre the fishes could not effectively check growth of *Hydrilla* in another similar pond. When the growth of weeds is not thick, complete clearance in the course of a month will be obtained with 30–40 fish per acre. All weeds are not equally relished by the fish. *Hydrilla*, *Lemna* and *Azolla* are avidly eaten, while *Pistia* and *Naias* are not favoured. *Ottelia* and *Lagarosiphon* are eaten to some extent. Leaves of *Jussea* are readily nibbled off. It has been observed that about 30 fish weighing about 40·8 kg. can easily consume about 27·2 kg. of *Hydrilla* per day. The large quantity of weeds eaten is perhaps only partially digested and the quantities of semi-digested weeds sent out as faecal matter add appreciably to the nutrients in the pond. Hence fairly thick plankton blooms are almost invariably found in the cleared ponds.

By March 1961, one specimen of Grass carp, 530 mm. long and weighing 1·6 kg., was found to be mature and oozing milt on slight pressure on the abdomen (age of this fish was about 22 months only). The outer surface of the pectoral fin was found to have developed roughness. This is a clear indication that the fishes are likely to mature during the ensuing monsoon season.

Specimens of Silver carp (*Hypophthalmychthys molitrix*) have been showing better growth than the Grass carp, the maximum size attained in 19 months (age 21 months) being 700 mm. and weight 4·15 kg. Two specimens examined on February 1961 were found to have developing gonads. The males had developed roughness on the outer surface of the pectoral fins. Indications are that these fish are likely to attain sexual maturity by the onset of monsoon in June–July.

A preliminary experiment on the growth of Silver carp was carried out to compare the same with that of Catla. Under identical conditions during

a period of three months, the Silver carps were found to grow about 50% faster than Catla.

Three specimens of Big head (*Aristichthys nobilis*), which have come along with the Silver carps, have been growing well, the biggest being 670 cm. long and 4·3 kg. in weight. All the three specimens appear to be females and by February 1961 they were found to be in a fairly well-developed stage of maturity. This is clear evidence that the major species of Chinese carps could attain sexual maturity in our ponds when they are only about 2 years old.

6. *Nursery Operations*

As spawning of Common carp continued throughout the year, the nursery ponds at Killa were put to use repeatedly for rearing successive crops. In the other ponds, only one crop of spawn was reared during July–August. All the ponds in Jobra, Puri and Choudwar could not be stocked. At Choudwar the entire stock of fry (6 lakhs) was washed off during high floods. The ponds at Linghipur and Kausalyaganga were stocked with relatively less fry for experiments on soil composition and on manurial value of selected chemicals. Stocking density was 2 lakhs/acre at Linghipur and 6 lakhs/acre at Killa.

All the ponds were initially manured with cowdung at the rate of 4 tons/acre. Mustard oil - soap emulsion was invariably applied to eradicate predatory insects. The fry were artificially fed with a 50 : 50 mixture of mustard oil-cake and rice bran, at a progressively increasing rate starting from about 3 times the initial weight at stocking. The number of fry and fingerlings harvested are as follows:—

	Catla	Rohu	Mrigal	Common carp	Calbasu	Total
Killa ..	1,10,200	2,88,000	47,000	3,40,000	..	7,85,200
Jobra ..	..	1,25,000	1,95,000	..	5,300	1,49,800
Puri ..	..	5,21,000	..	75,500	..	5,96,500
Linghipur ..	..	34,000	..	..	..	34,000
Kausalyaganga ..		1,71,650	..	..	..	1,71,650
						17,37,150

When the spawn produced from a pair of Catla was reared in nurseries, a good number of them turned out to be albinos. Instances of albinism in any of our carps are not known to have been observed before and hence the albino fry were segregated and reared in a separate pond. Nearly 50 specimens are now surviving and the maximum weight attained is 0·6 kg. in 8 months.

7. *Fish Production in Rearing Ponds*

Three rearing ponds, each 0·2 acres in area, stocked with 1–1½″ fry of Catla and Rohu were harvested after a period of 5½ months. Artificial food was given for two months in the beginning, the quantity introduced being 40·8 kg. of mustard oil-cake and 40·8 kg. of rice bran. The quantities of advanced fingerlings and yearling-size fish harvested from these ponds were 170·1 kg. and 158·8 kg. from two ponds in 5½ months and 136·1 kg. from the 3rd in 8 months. These work out to 1,859·7, 1,723·6 kg. and 1,020·5 kg. per acre per annum respectively and may be considered as very satisfactory.

8. *Tilapia Investigations*

Regular harvesting of Tilapia has been in progress continuously for the past 3 years and 7 months from a one-acre pond at Killa. No manuring or artificial feeding has been done and hence the harvest taken may be considered as natural production. With regular harvesting the size of the marketable crop is maintained higher.

Preliminary experiments on the use of Tilapia as a forage fish for the murrel, *Ophicephalus striatus* were carried out. While the experiments have to be repeated with various predator-forage ratios, it is found that murrels could effectively control the rapid multiplication of Tilapia.

Though mono-sex culture of male Tilapia was found to yield larger specimens for marketing, it was found that female Tilapia accidentally get into the ponds and start breeding. It has been found difficult to continue mono-sex culture for considerable periods.

9. *Fish Culture in Paddy Fields*

The experiment in 8 plots at the Central Rice Research Institute, Cuttack, was completed during the year. Common carp, Rohu and Catla fingerlings were used for stocking at a total density of 1,250 per acre. Common carp constituted 60% of the stock. Four months after stocking, the plots were harvested. The maximum yield obtained was 37·2 kg. per acre, but wild fish constituted about half this. Common carp showed very low survival but

excellent growth was recorded. Survival in the case of Rohu and Catla was better, but growth and production were relatively poorer than in Common carp. Further experiments will be arranged as soon as fields are prepared for the next crop of paddy.

10. *Weed Control Investigations*

Further field trials indicated that ammonia is fairly effective against submerged weeds even when the ultimate concentration in the water is about 8–10 p.p.m. However, regeneration is more rapid than when the gas is applied at 15–20 p.p.m. The floating weed *Wolffia* and the emergent water lilies *Nymphaea*, *Nelumbo* and *Euryale* are also effectively killed by the gas. The cost of clearing weeds with ammonia worked out to approximately Rs. 300–350 per hectare metre.

In preliminary yard experiments ammonium sulphate at 200 p.p.m. killed *Hydrilla* completely in 3 weeks' time. Superphosphate at 200 p.p.m. killed 95% of the plants. N-P-K at 200 p.p.m. encouraged the growth of filamentous algae, without appreciably effecting *Hydrilla*.

In yard experiments, " taficide " (a new formulation of sodium 2, 4-D) at 5·6–11·2 kg./ha. killed water hyacinth and *Pistia* completely within 4–6 weeks. The 2, 4-Dichloropropionic acid preparation " Dowpon " was not found effective against *Hydrilla* grown in glass jars even at 50–100 p.p.m. Borax at 200 p.p.m. in cement cisterns did not have any sustained effect on *Hydrilla*. Aluminium sulphate applied at 50 p.p.m. in glass jars containing *Hydrilla*, after raising the pH of the water to 9 with shell lime, proved lethal to the plant. Further experiments have to be carried out for obtaining definite conclusions. Cobalt is under trial and has so far not shown any effect on *Hydrilla*, the strength used being up to 200 p.p.m.

A number of chemicals like ferrous sulphate, aluminium sulphate, sodium chlorate, sodium borate, sodium 2, 4-D (each at 225 kg./ha.), strontium chloride, sodium bismuthate, ammonium carbonate, barium chloride and carbolic acid (each at 561 kg./ha.) were screened for their potential value as soil sterilants. Of these, barium chloride alone gave complete suppression of the germination of *Hydrilla* turions. Others like sodium 2, 4-D gave partial suppression.

Three stocking tanks at Kausalyaganga (each 0·5 hectare) infested with *Hydrilla*, *Naias*, *Nymphaea*, *Nelumbo* and *Euryale* were selected for studying the comparative effectiveness and economics of ammnoia, urea and manual labour for clearing submerged and emergent weeds, one tank being used for

each mode of clearance. Seven to eight months after the start of the observations, there has been 5%, 10% and 15% regeneration of weeds in the tanks cleared with urea-*cum*-manual labour, with manual labour and with ammonia combined with some manual labour respectively.

A sample survey of the weed-infested waters of Andhra Pradesh has been taken up. Forty-two bodies of water in nine districts have been covered so far and the collections made during the survey are being analysed. Out of the nine districts studied, the deltaic regions of East Godavari, Krishna and Nellore have been found heavily infested with weeds.

11. *Soil Composition and Fish Production*

With a view to study the correlation between the available nutrient status of pond soil and production of fish, observations in selected ponds at Sambalpur, Berhampur, Puri, Balasore, Angul and Choudwar in Orissa were continued. Regular determination of water and soil qualities were carried out. The ponds were stocked uniformly with major carp fingerlings and production was assessed after 8 months. The results confirm the earlier observation that in slightly acidic or slightly alkalinic soils with fair concentration of available nitrogen, soil phosphorus is likely to play an important role in determining production.

A laboratory experiment using a series of glass jars was taken up to determine whether different levels of available phosphorus in soil has any effect on the production of plankton. Phosphorus was artificially raised to 8, 12 and 16 units (mg./100 gm.) by adding double superphosphate. Plankton was uniformly inoculated in the jars and the water conditions were studied at weekly intervals. It appears that plankton production could be directly correlated with available phosphorus. The experiments are being continued.

In a field experiment in the nursery ponds at Linghipur, starting with two different levels of phosphorus (4 and 8 units), the same trend of production as in the experimental jars was obtained. Observations in six other ponds at Linghipur showed the same trend so far as fish production during the dry stage is concerned.

Some preliminary experiments, conducted in cement cisterns to find out the effect of addition of manganese, indicate that there is definite increase in the quantity of plankton produced when treated with trace elements. Here also it was noted that high plankton concentration coincided with high phosphorus and manganese in water.

Results obtained from another series of laboratory experiments indicate that when the pH was lowered from 7·3–3·5, there was a sudden rise of phosphate in water which was more or less maintained till the end of the experiment when the pH rose to 6·8. Increase in the case of manganese and copper was slow and there was very little increase in the case of iron which showed a diminishing trend when the pH reached neutrality. In the case of alkali treatment, manganese faded away to minimum when the pH was raised from 7·3–11·0 and reappeared when pH was lowering down. Phosphate showed diminishing trend.

12. *Miscellaneous Studies*

About 150 samples of plankton were analysed to find out the correlation between plankton concentration estimated gravimetrically and by photoelectric absorption through a suitable filter. The correlation curve shows a linear relation between plankton weight and photoelectric absorption in majority of cases.

Various methods of collection of plankton have been under trial in order to find out the most representative sampling technique. Appreciable quantities of silt found in most of the collections could be satisfactorily removed by fractional separation using chloroform as a coagulant.

Observations on the formation of pearls induced by mantle grafts in the freshwater mussel *Lamellidens* were continued. During a period of one year the survival of operated shells was found to be about 40%. All the operated shells produced tiny pearl concretions at the place where mantle grafts were introduced. Size of the pearls ranged from 0·2 to 2·0 mm. but only a very small fraction were of regular shape.

Riverine and Lacustrine Division

13. *Catch Statistics and Disposition of Fisheries in the Ganga River System*

The total landings from the main river Ganga has been estimated to be 1,015·7 metric tons during the period April 1960 to March 1961 as against 899·6 metric tons in 1959–60, thus registering a rise of 21·91%. The maximum catches were landed in December (147·6 metric tons) and November (138·6 metric tons) and the minimum in August (21·9 metric tons).

The yield of major carps amounted to 158·2 metric tons, as against 224·8 metric tons during the previous year. The yield of *C. mrigala* was 62·69 metric tons, *C. catla* 50·5 metric tons, *L. rohita* 38·6 metric tons and *L. calbasu* 6·398 metric tons.

The catch of large catfishes for the current year was estimated at 290·5 metric tons. The landing of *Mystus aor* was 64·6 metric tons, *M. seenghala* 27·9 metric tons, *W. attu* 57·1 metric tons, *S. silondia* 22·5 metric tons, *P. pangasius* 99·5 metric tons, *Rita rita* 12·3 metric tons and *B. bagarius* 6·7 metric tons. In spite of decrease in yield from *M. aor*, *S. silondia* and *B. bagarius*, the large catfishes have shown an overall net increase of 10·42%.

The landing of *Hilsa ilisha* constituted 308·7 metric tons as against 154·7 metric tons of the last year. The total landing of prawns and shrimps was 25·5 metric tons, there being a net difference of 3·6 metric tons, registering 16·58% increase over the previous period. The landing of tortoise amounted to 4·7 metric tons.

The annual landing in the Jumna river has been estimated to be 312·7 metric tons as against 545·3 metric tons in the previous year. The landing of major carps amounted to 158·2 metric tons which was less than that in the previous year (1959–60) by 124·6 metric tons. The fishery of *C. mrigala* amounted to 97·9 metric tons, *C. catla* 22·8 metric tons, *L. rohita* 23·7 metric tons and *L. calbasu* 13·8 metric tons.

The landing of large catfishes amounted to 102·2 metric tons, as against 1,83,114 kg. of preceding period. The fishery of *M. aor* constituted 40·9 metric tons, *M. seenghala* 18·4 metric tons, *W. attu* 15·5 metric tons, *S. silondia* 9·4 metric tons, *P. pangasius* 6·4 metric tons, *R. rita* 6·9 metric tons and *B. bagarius* 4·7 metric tons.

The landing of Hilsa amounted to 24·1 metric tons as against 28·0 metric tons of 1959–60. The landing of prawns and shrimps constituted 0·9 metric ton.

14. *Catch Statistics of Narbada River*

The sampling technique of market survey for estimation of total fish production in the Narbada river was given effect in December 1960. For this purpose the stretch of 450 miles of Narbada river in Madhya Pradesh has been subdivided into three fishery zones, each about 150 miles in length. The species composition of the catches in Western Zone (Khandwa to Barwani) was found to be as follows: *B. (Tor) tor* (28·1%), *L. fimbriatus* (22·1%), *M. aor* (6·8%), *M. seenghala* (5·6%), *L. calbasu* (5·0%), *R. pavimentata* (2·7%), *Ophicephalus* spp. (2·6%), *L. bata* (1·8%), *L. dyocheilus* (1·2%), *O. bimaculatus* (0·8%) and *C. catla* (0·4%). In the Central Zone (Udhiapura to Harsud) the predominant species in the catches were *B. (Tor) tor* (30·1%), *L. fimbriatus* (24·4%), *M. seenghala* (10·8%), *M. aor* (9·1%), *W. attu* (4·4%),

B. sarana (3·5%), *R. pavimentata* (3·0%), *L. bata* (2·9%), *Ophicephalus* spp. (2·0%), *C. mrigala* (1·8%) and *C. garua* (0·8%). In the Eastern Zone (Mandla to Gadarwara) the catches were represented by *B. (Tor) tor* (25·3%), *L. fimbriatus* (21·5%), *W. attu* (10·5%), *M. seenghala* (8·2%), *M. aor* (6·5%), *R. pavimentata* (6·4%), *Ophicephalus* spp. (4·2%), *L. calbasu* (3·7%), *B. sarana* (3·6%), *M. armatus* (1·9%), *L. bata* (1·4%), *C. mrigala* (1·2%), *L. gonius* (1·1%) and *C. catla* (0·5%). Thus it is seen that in Narbada river fishery of *B. (Tor) tor* and *L. fimbriatus* is the most important, followed by *M. seenghala* and *M. aor* in Central Zone, *W. attu* and *M. seenghala* in Eastern Zone and *M. aor* and *M. seenghala* in Western Zone.

Detailed studies on the disposition of commercial fisheries were limited to a 30-mile stretch of Narbada in Central Zone which includes two important landing centres, Hoshangabad and Shahganj. In this stretch the annual catches were estimated to be 36,640 kg. The catches were represented mainly by *B. (Tor) tor* (26·9%), *L. fimbriatus* (19·0%), *Rita pavimentata* (15·1%), *M. seenghala* (8·4%), *W. attu* (7·0%), *L. calbasu* (3·3%) and *M. aor* (3·3%).

The dominant size groups were:—

B. (Tor) tor	..	230–405 mm. (50·9%); 410–610 mm. (30·7%)
L. fimbriatus	..	330–455 mm. (50·4%); 180–305 mm. (38·5%)
R. pavimentata	..	130–200 mm. (73·8%);
M. seenghala	..	280–455 mm. (33·0%); 480–635 mm. (39·3%); 600 upward (30·5%)
W. attu	..	480–635 mm. (42·7%)

The observations on the catch per unit of effort in respect of cast net and long line operations were continued at Shahganj centre.

381 cast nets were operated for a total period of 3199 hours and the average catch per net per hour was found to be 0·36 kg. (Range: 0·19 kg. in January 1961 to 0·51 kg. in September 1960) 1960–61, as against 0·41 kg. (Range: 0·21 kg. in March 1960 to 0·72 kg. in July 1959) in 1959–60.

350 long lines were operated for a total period of 4017 hours and the catch per unit of 500 hooks per hour was 0·20 kg. (Range: 0·09 kg. in March 1961 to 0·31 kg. in July 1960) in 1960–61 as against 0·19 kg. (Range: 0·09 kg. in July 1959 to 0·44 kg. in August 1959) in 1959–60.

15. *Catch Statistics of Godavari River*

The collection of catch statistics and studies on disposition of the commercial fisheries in the Godavari were limited to a 25-mile stretch of the river

near Rajahmundry. This section is reckoned as the most productive and during the year, 254·7 metric tons of fish were landed here. Comparative study of monthly catches shows a marked improvement in summer and monsoon. The summer fishing is essentially constituted by carps, prawns and catfish. Monsoon fishing was monopolised by bumper Hilsa harvest. The percentages of the groups in the annual catches were carps 16·44% (41·8 metric tons); catfishes, 14·86% (37,898 kg.); Hilsa, 28·10% (71·5 metric tons); prawns, 14·95% (38·0 metric tons) and miscellaneous group, 25·65% (65·3 metric tons). Among the carps, the fisheries of *L. fimbriatus* and *C. mrigala* were most dominant and that of *M. seenghala* among catfishes. It was observed that the first-year groups dominated the commercial landings particularly of carps and catfishes and made up 38·6% of the total annual catches of these groups respectively.

16. *Biological Investigations*

Over 665 specimens of *Mystus aor* and 330 specimens of *M. seenghala* were measured during the year. The sex ratio in *M. aor* has been calculated to be 1 M: 1·3F, and in *M. seenghala* 1 M: 1·7 F. The females of *M. aor* were found to be dominant in the months June–February and of *M. seenghala* in April–November.

On the basis of diameter measurements of 300 ova of each ovary, 10 arbitrary stages have been defined which correspond to the International scale adopted for sea fishes. The progression of the two right-hand modes have been compared by means of a scatter diagram, wherein the position of the last group of most mature ova (Y) is plotted against the position of the mode of the preceding group (X) in 50 ovaries representing D to I stage of maturity. A high coefficient of correlation of 0·720 (PL 0·05) emphasises the close relationship between the progression of the succeeding modes, so that it is established that groups of small ova grow to maturity and will also mature in their turn within the same spawning season. The ratio of the maturing and mature ova in the ovaries of F stage has been collected month-wise and the minimum value of ratio of 1 to 0·8 in April suggests peak breeding period. Thus the multiplicity of the modal group and a high correlation between the modes of successive groups and the decrease with the advent of spawning season in the proportionate number of the ova forming the intermediate groups provide sufficient evidence that individuals of *M. aor* spawn more than once in a breeding season. It is seen that ovaries in immature intermediate stages are recorded almost throughout the year, although majority of immature ones are encountered in August to February. Majority

of mature ovaries are recorded in the months February to July. *Mystus aor* breeds during early March to end of August. The collection of large number of early larval stages during the period supports this conclusion.

The minimum size at which the first maturity is attained in *M. aor* is above 820 mm. when the fish has entered the third year of its life. The relationship between ova number and length and weight of the fish is found to be:

$$Y = 1 \cdot 85027 + 1 \cdot 04325 \log T.L.,$$

and

$$Y = 2 \cdot 53240 + 0 \cdot 63993 \log W.$$

Relationship between length of ovary (Y) and length of fish and between length of testes (Yt) and length of fish is found to be:

$$Y = -1 \cdot 76952 + 1 \cdot 30263 \log T.L.,$$

and

$$Yt = -1 \cdot 07750 + 1 \cdot 07687 \log T.L.$$

Relationship between weight of ovary and the number of ova spawned (fecundity) has been found to be:

$$Y = 3 \cdot 60257 + 0 \cdot 68189 \log W.,$$

or

$$Y = 4005 + 0 \cdot 68189.$$

The analysis of covariance and the test of significance performed for the males (4 years' samples combined) and the females for the same period yield high values of F, thereby showing that the differences in the values of 'b' for males and females are highly significant. The test of significance has also shown that the differences in the values of 'b' with different samples (males and females separately) are highly significant.

243 stomachs were examined and the data show that the fish subsists on teleosts (58·7%), insects (27·73%), crustaceans (8·21%) and plant debris (5·36%). The feeding activity does not follow any set pattern and the stomachs examined showed generally poor feeding activity almost throughout the year. Mature specimens during the period April–June were with almost empty stomachs. Monthly fluctuations in the volume of the different food items have shown that there is no selectivity in feeding habits and it is observed that absence of insects as item of diet during July–September is perhaps due to high flood conditions prevalent in the rivers. The analyses

of gut contents of juveniles show that there is no marked difference in the food habits of adults and juveniles. The food habits reveal that the fish is a column and marginal feeder.

Length/frequency analyses indicate that commercial fishery of *Catla catla* is represented by 8-year classes as follows:

Age	Mean size	Size range
I	285	270–300
II	455	440–470
III	655	640–670
IV	810	795–825
V	890	875–905
VI	950	935–965
VII	995	980–1,010
VIII	1,035	1,020–1,050

The scale length (Y) and fish length (X) show a high degree of correlation with value of $r = 0{\cdot}98946$, and the relationship is expressed as:

$$Y = -1{\cdot}638449 + 2{\cdot}9141^{(10-2)}\ X.$$

Specimens in advanced stages of maturity occur in May and June. August seems to be the peak breeding period. There appears to be some functional relationship between number of ova and weight of ovary but the same cannot be said with reference to weight of ovary and length of fish. The fecundity of eight ovaries of weight ranging from 301 gm. to 3,118 gm. was found to be between 2,30,831 and 29,63,125 ova. The sex ratio for the year was calculated to be 1 : 1.

The food of the fish comprises mainly of crustaceans. On the basis of data arranged separately for each of the four quarters of the year, crustaceans ranged between 42·5% and 61·3%; algae 11·4% to 13·6%; plant matter 2·8% in January–March quarter to 14·4% in October–December quarter; insects 4·0% to 12·0%; and lotifers 1·4% to 11·3%. Feeding intensity was found to be low during the breeding season.

Juveniles (56–147 mm.) dominated the *Silonia silondia* catches at Allahabad in August and September. Mature specimens were observed during June to August and spent fish in August. Specimens with spent ovaries, encountered in December, seem to indicate prolonged breeding but more evidence in this regard is necessary. Fecundity of one specimen (1062 mm. T.L.) with ovary weighing 252 gm. was calculated to be 4,87,901. Age and growth are being studied by L/F method and markings on vertebral centra. Markings seem to be indicative of age and the first ring is found after the fish has attained 173 mm. in total length. In the size range 1,062–1,306 mm., 7–8 rings are observed. The fish subsists mainly on teleosts (30·1–71·1%) followed by insects (10·1–41·2%), plant matter (7·2–11·4%) and prawns (4·4–8·3%).

241 specimens of *Barbus* (*Tor*) *tor* (size range 210–785 mm.) were examined for biological studies. The trend of feeding activity, as determined by gastrosomatic index and ' condition ' of guts, has shown that the fish feeds actively from November–June (G.S.I.: 5·1) and poorly from July to October (G.S.I.: 1·8). This species was found to subsist mainly on macrovegetation (45·0%), molluscs (13·8%), filamentous algae (12·5%) and insects (5·1%). The macrovegetation was comprised of *Vallisneria*, *Ceratophyllum*, *Naias*, *Hydrilla* and *Chara*. *Spirogyra*, *Zygnema* and *Mougeotia* were common among filamentous algae. Diptera larvae, Caddis fly larvae, Dragon fly nymphs and water bugs constituted the insect diet. The gross examination of the gonads and gonado-somatic index have shown that this species commences breeding in August which is continued up to January. The availability of large number of post-larvae of size range of 9–12 mm. from August to January and occurrence of partly and completely spent ovaries in the same period fully support these observations. The ovaries were mostly found to be maturing in April–June (G.S.I.: 6·8), maturing and ripe in July–September (G.S.I.: 15·1), ripe and partly or completely spent in October–December (G.S.I.: 7·0) and resting stages in January–March (G.S.I.: 5·1). The first maturity of this species (both sexes) is attained in the size range of 270–290 mm. The fecundity of nine specimens in the size range 283–750 mm. was found to be ranging between 7,000 and 1,00,000.

The size-group 125–250 mm. was the most dominant in *Rita pavimentata* catches. The catch per unit of 500 hooks per hour was found to be 0·13 kg. as against 0·12 kg. in 1959–60, when prawn, earthworm, dragon fly nymphs, fish, gastropods, wheat and filamentous algae were commonly used as baits.

The observations on the diet of adults have shown an upward trend in the feeding activities from April to July. The data on gastrosomatic index and 'condition' of stomach have shown the same trend. The fish subsisted on molluscs (37·7%), macrovegetation (6·1%), teleosts (5·6%), prawns (5·3%) and insects (1·4%). The examination of 190 stomachs of juveniles (below 125 mm. total length) from July–October has shown that the feeding activity which was intensive in July–August (average feed: 0·05 c.c.; G.S.I.: 1·81), declined in September–October (average feed: 0·04 c.c.; G.S.I.: 1·21). The main food items were found to be prawns (22·7%), insects (14·4%), macrovegetation (4·8%) and teleosts (1·8%). The gross examination of the gonads and the ova diameter studies have indicated that this species commences breeding in June–July as was observed in the previous year. The gonads were mostly immature and maturing in April (G.S.I.: 1·4), maturing and ripe in June (G.S.I.: 2·89), ripe and partly spent in July–August (G.S.I.: 5·43 and 8·91 respectively) and spent in September (G.S.I.: 2·48).

Prawn fishery in Godavari appears to extend up to 900 km. from the sea, but smaller size-groups dominate in the lower reaches and larger size groups in the upper reaches. Over 8,000 specimens of *Macrobrachium malcolmsonii* were examined during the year. The length frequency analysis showed that males in the catches were comparatively smaller than females during April–September and thereafter large size-groups of males dominated the catches, particularly during the period October–February. Winter and summer catches were dominated by males, but in intermediate months females dominated. Females mature when they attain the length of 50 mm. during their first year. The length range of berried females observed is 52·0–165 mm. Fecundity appears to increase with the increase in size of the prawn and breeding commences with the onset of first monsoon rains and extends over 5 months. The data seem to suggest that females breed more than once in a single season. The incubation period is observed to be 12 days for both *M. malcolmsonii* and *M. scabriculus*.

17. *Stream Pollution Studies*

Studies on the impact of pollution of sugar and distillery wastes belonging to Messrs. S. K. G. Sugar Mills, Hathua and Siwan Sugar Mills, Siwan, on the small stream Daha in the Siwan Subdivision of Saran District (North Bihar) were undertaken. River Daha is a perennial meandering stream from overflow of a large Jheel (Sasamusa cher) and joins the river Gogra some 30 miles below Siwan.

Results based on eight observations indicate that during the premonsoon months, except on two occasions, apparent severe pollutional conditions did not prevail. Even though D.O. was low (3·1–4·4 p.p.m.), B.O.D. value never went high (2·0–7·3). During the monsoon months conditions improved, but at Renua, due to admixture of distillery wastes, the river was affected for a short length (D.O. 0·05 p.p.m. and B.O.D. 20·0 p.p.m.). Post-monsoon months showed high degree of pollution between Renua and Singahi due to intensified bacterial activity and stagnations (D.O. 0·48–1·8 p.p.m. and B.O.D. 60·87 p.p.m.). The stretch above Renua did not show any pollutional features. During the next monsoon conditions, all signs of pollution disappeared (D.O.—5·4–7·6 p.p.m.; B.O.D. 6·8–7·2 p.p.m.) in the entire stretch. Nutrients like nitrates and phosphates showed high values. Since there is little flow, natural aeration does not occur, but from 4 hourly sampling anaysis for D.O over 24 hours, it appears that the thick growth of submerged vegetation contributes a high measure of D.O., helping in the purification of water.

On two occasions fish mortality occurred. Distillery wastes of low pH and high oxygen demand reduce the ferric iron into ferrous state which on contact with oxygenated alkaline water is reconverted into ferric state and thereby reduce the D.O. content. Fine precipitation of ferric iron on the gills also reduce the capacity of fishes to absorb the little amount of oxygen present in the water and thus endanger the fish life.

46 species of fish were collected of which *Ambassis nama* (41·7%), *Gadusia chapra* (22·8%), *Oxygaster bacaila* (13·3%), *Mystus vittatus* (10·2%), *Puntius sophore* (10·0%), *Puntius chola* (10·0%), *Labeo rohita* (1·6%), *Catla catla* (0·4%) and *Cirrhina mrigala* (1·9%) were dominant forms. The occurrence of catfishes like *Wallago attu*, *C. garua*, *E. vacha* and some *Mystus* spp., as also the major carps was restricted mostly to postmonsoon months. A decline in major fish population is directly attributable to conditions of pollutional features. The stomach analysis of 265 specimens obtained from all points revealed that they thrived mostly on the bottom biota, aquatic oligochaetes, chironomids and insects.

Bio-assay experiments using *Puntius sophore* as test fish indicated that distillery effluents have toxic range between 6·03 and 8·14% when fish are 78·8 mm. (av. T.L.) and 9·23 gm. (av. wt.). Raw undiluted sugar waste did not show any toxicity even after 24 hours. Complications arise only when these sugar wastes are subjected to bacterial activity.

With test fishes *P. sophore* and *M. vittatus* of average size 38–73 mm. and 45–93 mm. and corresponding average weights 0·6–4·2 gm. and 0·6–6·9 gm., pulp waste showed the T.L.m. values between 23·24–26·99% and 31·34–36·41%. For paper waste and combined waste of pulp and paper, both the fishes showed similar toxic range.

18. *Ecological Investigations in the River Ganga*

The ecological study in the stretch of 700 miles of river Ganga was completed by the end of January 1961. The regular collections and analysis of plankton, bottom biota, and water samples were made at all the seven collecting stations. Rise in the plankton quantity was observed from April–June. The average monthly plankton was highest in June at Varanasi (57,127 per litre), followed by Allahabad (26,347 per litre), Kanpur (47,317 per litre), Rajmahal (7,932 per litre), Ballia (3,712 per litre), Bhagalpur (2,135 per litre) and Patna (1,321 per litre). From July, *i.e.*, with the onset of rainy season, the plankton showed a sharp decline with considerable rise in turbidity and the velocity of current. The minimum quantity of plankton was observed during September.

Chlorophyceae remained dominant at all the centres throughout the period, except at Kanpur in May which was probably due to the bloom of *Nostoc* and *Anabaena*. Most widely represented species of Chlorophyceae were *Mougeotia*, *Spirogyra*, *Pediastrum*, *Actinastrum*, *Eudorina*, *Pandorina* and *Scenedesmus*. Bacillariaceae was represented by *Synedra*, *Nitzschia*, *Navicula*, *Fragillaria*, *Gomphonema*, *Gyrosigma*, *Diatoma* and *Pleurosigma*. *Anabaena*, *Nostoc*, *Microcystis*, and *Merismopedia* were the important species forming Myxophyceae group.

Zooplankton also had the similar trend of rise and fall as that of phytoplankton. The maximum monthly average zooplankton was recorded in June. Zooplankton became minimum in September at all the centres, fluctuating between 9 and 46 units per litre. Rotifers, represented by *Anuraea*, *Brachionus*, *Filinia*, *Polyarthra* and *Rattulus*, were the most dominating forms. *Nauplius* and *Cyclops* among copepoda, and *Ceriodaphnia* and *Bosmina* among cladocera were obtained frequently.

The benthic organisms did not show any regularity in occurrence. The maximum number of organisms were obtained at Patna in September, the value being 1,110 per square foot. The other values obtained were: at Varanasi in June 661 per square foot, at Rajmahal in May 117 per square foot, at Allahabad in June 87 per square foot, at Bhagalpur in July 16 per square foot, at Kanpur in April 5 per square foot.

The average pH at all the centres was 8·1 except at Kanpur and Allahabad where the same was 8·2 due to excess of bicarbonates. The dissolved oxygen ranged between 3 and 8 p.p.m. Chloride showed maximum value in June (23 p.p.m.) and minimum (4 p.p.m.) in monsoon season. Silicate was maximum in May (19 p.p.m.) and minimum in July (4 p.p.m.).

In the Jumna a gradual fall in pH was observed from 8·0–7·5, due to the dilution of wastes during rainy season. Alkalinity was mainly because of bicarbonates, ranging between 50 and 156 p.p.m. Inorganic nutrients such as nitrate and phosphate registered a sudden rise in July and then gradual fall from August onwards. Calcium showed maximum concentration in October (52 p.p.m.) and minimum in July and August (15 p.p.m.). Before the onset of rainy season the concentration of nutrients was higher at banks than in the midstream. Nitrate showed a difference of 0·03 p.p.m., phosphate 0·04 p.p.m. and silicate 3 p.p.m. During the rainy season a general rise in the concentration of these nutrients was observed both in midstream and at margins.

19. *Location of Fish Breeding Grounds and Carp Collection Centres*

Over 35,000 Hilsa eggs were collected during the period 2nd July 1960 to 19th September 1960 at Poicha (20,000 eggs), Malsar (15,000 eggs) and Mangrol (26 eggs). This indicates that an 18-mile stretch of Narbada between Poicha and Mangrol constitutes the spawning ground of Hilsa. This confirms the earlier observations made during the previous year. Indications are that spawning season of Hilsa commences in June–July and continues up to September with peak breeding in August when the maximum flood level is attained in the river. Breeding is observed to have taken place in early morning hours between 2·0 A.M. and 6·0 A.M. It is also observed that upstream migration and breeding activities of Hilsa are correlated with lunar and high flood periodicities. Males appear to ascend earlier in the seasons than the females. The length frequency data showed that older size groups penetrate freshwaters for breeding and that Narbada Hilsa attain maturity at higher length as compared to Gangetic Hilsa.

Investigations on availability of carp seed in Narbada were regularly carried out. At the three centres Poicha, Malsar and Mangrol in Gujarat State considerable quantities of seed were collected. Malsar centre appears to be quite productive and over 1,30,50,000 carp fry were collected in the 2–3 nets operated for 202 hours on 37 days. The percentage of major carps in the samples reared was calculated to be 94·0%.

In the Godavari river at Rajahmundry it was observed that spawn during monsoon season is composed of nearly 37 species (excluding the catfishes) of fish. Of these, six are major carps, seven minor carps, eight barbels and sixteen carp minnows and forage fishes. High percentage of major carps in the spawn occurs in July during the first two floods and spawn of *L. fimbriatus* is dominant throughout the season July–September. Each species tends to indicate a peak period comprising a few days when they occur in largest numbers and therefore it appears to be feasible to predict the period when maximum collections of major carps could be made.

20. *Basic Surveys of Rivers*

The inventory survey of fishing villages in the 230-mile stretch of Tapti river from Tedtalai to Kathora in Madhya Pradesh and Maharashtra State and from Nengri to Surat in Gujarat State has been completed. In the five districts so far covered, there are 196 villages with a total population of 71,740, of which 7,415 are active fishermen. The largest number of nets were gill nets (11,858), followed by fishing rods (5,215), Hilsa jal (3,441), cast net (2,298), traps (1,925), scoop nets (1,685), long lines (1,383), bag nets (441) and drag nets (60).

The preliminary survey of the Godavari river was completed during the early part of the year. In the 672 villages, the active fishermen population is 12,854. Among the fishing gears the most important are drag nets (12,08,770 pieces), hook and lines (18,766 nos.), cast nets (14,215), dip nets (2,423) and scoop nets (486). The data show that a long stretch of nearly 345 miles between rivers Purna and Pravara is the least productive and most underdeveloped region. Among the fisheries, *L. fimbriatus* appears to be widely distributed and fisheries of *Catla*, *Mrigal* and *Calbasu* appear to be limited to lower reaches. The catfishes have much wider distribution and of these, *M. seenghala*, *M. aor*, *Wallago attu*, *P. pangasius*, etc., are the more important fisheries. *Hilsa* fishery is restricted to lower reaches up to Dowleiswaram and prawn fishery is extremely important particularly during summer months.

The preliminary survey of the Krishna river which was initiated during April 1960, was completed in October 1960. In the 1278 km. stretch, there are 156 villages with 3,030 active fishermen, 4,224 cast nets, 368 drag nets, 991 gill nets, 171 dip nets and 1,15,124 hooks. The fisheries of Krishna river are extremely poor excepting in the lowermost reaches.

A survey of Sardasagar, an irrigation reservoir in Pilibhit district of Uttar Pradesh, and the Sarda river drainage was undertaken to investigate

the problem of possible escape of major carp fingerlings through the outlet channel. The fish fauna survey, which included the evaluation of relative abundance of various species of Sarda river, Chuka nadi above and below the reservoir and Sardasagar, clearly showed that there is very little possibility of any large-scale fish escape through the outlet channel. So it was recommended that there is no need to provide any fish screens for preventing fish escape. A detailed scheme for proper development of Sardasagar has been suggested.

21. *Lacustrine Investigations*

During the year under report 21·16 metric tons of fish were estimated to have been sold in the Hospet fish market. Carps predominated during June–November. During other periods siluroids predominated. *Barbus* spp., 40·61%; (of this *B. kolus* formed 30·7%); *Labeo* spp., 23·1%; Siluroids 33·9%; Murrels and others 3% were the other important groups. The peak periods of production were September–October/November and March–April.

Length frequency data analysed indicated that unimodal curves are given by *B. kolus*, *S. silondia*, *B. pinnauratus*, *B. pulchellus*, *Labeo calbasu* and *L. potail*. Multimodal curves are given by *L. fimbriatus*, *B. dobsoni*, *B. tor*, *Wallago attu*, *Mystus aor* and *M. seenghala*. Further observations are being made to find whether this is due to selectivity of gear or predominance of certain age groups.

Average catch per month (species-wise) is as follows: *B. kolus* 528 kg., *B. dobsoni* 88·7 kg., *B. pinnauratus* 42 kg., *B. tor* 28 kg., *B. pulchellus* 11·2 kg., *L. fimbriatus* 316 kg., *L. calbasu* 44·3 kg., *L. potail* 25 kg., *L. nukta* 4·3 kg., *Mystus aor* 248 kg., *M. seenghala* 144 kg., *W. attu* 36·6 kg. and *Silonia silondia* 29 kg.

Fishing in the Reservoir was done for 615 days. Departmental Uduvalai nets of 1·5″ and 2″ mesh and Rangoon nets of 2·5″, 3″ and 3·5″ mesh were used for this purpose. From end of November onwards, the Rangoon nets prepared by Mr. Gulbadamov (F.A.O. Expert) were employed and these increased the catches considerably. The composition of catches (by weight) was as follows: *B. kolus* 1·5″—67%, *B. pinnauratus* 1·5″—95%, *B. dobsoni* 2·5″—31%, *B. tor* 3·5″– 76%, *Rohtee vigorsii* 1·5″—100%, *B. pulchellus* 2″—41%, *Labeo calbasu* 2″—48%, *L. fimbriatus* 2″—43% and *Mystus seenghala* 2″—55%.

Sex ratios in most of the species were 1 : 1 or 1 : 1·5 (male : female), but in *Rohtee vigorsii* it was 1 (m) : 18 (f) and in *M. seenghala* 1 (m) : 3 (f). The

number of eggs and their size frequency have also been studied. Length-weight relationship and relative condition factor was calculated for six species. Growth rate was studied in *L. potail*, *L. nukta*, *Scaphiodon thomasi*, *B. dubius*, *B. carnaticus* and *Cirrhina cirrhosa* by means of observation of scales. It was seen that *Neotropius khabalchor* feeds on the scales of the carps and this may be responsible for many regenerated scales found in the fish from this reservoir. This fish takes to feeding of scales when over 1·5″ in length.

An interesting observation has been made regarding *Rohtee* sp. Small fish (up to 6″ long) of this species are eaten by siluroid fishes. The dorsal spine of *Rohtee* is erected and gets stuck up on the gullet of the predator and this keeps the mouth of the latter open and in course of time it dies. During December and January many silurids (*Silonia silondia*, *Mystus aor* and *Mystus seenghala*) were found floating dead in the reservoir. Invariably all these fishes had *Rohtee* stuck up in their gullets.

During the greater part of the year (from April–October 1960), the Unit took part in experimental fishing conducted by F.A.O. Gear Technician Mr. Gulbadamov in Mettur Reservoir, Krishnaraj Sagar and Maithon and Panchet Hill reservoirs. Surface gill nets (2–5″ mesh), bottom-set gill nets (1·5″ and 2″) and monofilament nets were used. The nets, which are modifications of the local Rangoon and Uduvalai nets, gave comparatively better catches. Data on length, weight, sex, etc., were collected from fishes caught in different meshed nets.

The catches obtained by the modified nets at Mettur Dam were more than double that caught with local gear. *Cirrhina cirrhosa*, *Pangasius pangasius*, *Silonia silondia* and *C. mrigala* contributed mainly to the catches. The average sizes (in mm.) of these species obtained in different nets were:

Species	Mesh		
	2″	2·5″	3″
C. cirrhosa ..	499	498	511
C. mrigala ..	556	441	696
Silonia silondia ..	389	416	463
Mystus seenghala ..	487	..	854

Nets with 2–5″ mesh were used in Mettur and Panchet reservoirs. Mrigal formed 20·7% of the catches, *L. calbasu* 23·4%, *B. sarana* 19·2%, *Wallago attu* 9%, *Catla catla* 7·6% and Rohu 7·3%.

Fishing with Electric lamps, using red, orange, blue, green and yellow lights was done, but this did not prove successful for large-scale fishing. Fishing with electric current was also tried at 5–40 volts, but this experiment also did not give expected results.

At Krishnaraj Sagar experimental fishing was done during July and August. The catch per net per day in different meshed nets were as follows:

Rangoon net 2″—11·16 kg., 2·5″—12·57 kg., 3″—6·88 kg., 3·5″ and 4″—2·99 kg. and 4·5″ and 5″—0·952 kg., and Uduvalai nets of 1·5″ and 2″—3·26 kg. *Barbus dubius* and *B. carnaticus* contributed mainly to the fishery. The average sizes of the two species obtained in different nets were:—

	Mesh		
	2″	2·5″	3″
B. carnaticus ..	456	524	586
B. dubius ..	398	470	524

Plankton studies conducted in the Tungabhadra Reservoir indicated that zooplankton predominated over phytoplankton. Among the zooplankton, the order of predominance was Copepoda, Rotifers and Cladocera. Among the phytoplankters the order was green algae, diatoms and blue-green algae.

The maximum surface temperature of the reservoir water recorded during the year was 32° C. and minimum 23·8° C.

The difference of temperature from surface to bottom during February–May period usually exceeded 2·5° C., while during the rest of the year, it was rarely more than 1° C. No permanent thermocline formation was observed. The pH varied between 8·4 in June and 7·3 in August. The maximum turbidity recorded was 104″ in February and the minimum 4″ in August. The maximum dissolved oxygen content noted at surface was 8·0 mg./l. in January and the same at bottom was 7·70 mg./l. in February. There was an enormous increase of phosphates and nitrates during August when flood water entered the reservoir.

Estuarine Division

22. *Investigations on the Fisheries of the Hooghly-Matlah Estuarine System*

Intensive studies on the 26 selected species of fishes and 5 of prawns were continued. A study of the variation patterns of effort and catch per unit effort between centres of the same zone and days within centres has shown that the variation in the former is much higher than in the latter. Therefore, the number of sampling centres was increased from three to four per zone, with a simultaneous reduction in the number of sampling days from three to two in a fortnight per centre. The combination of sampling survey and total enumeration methods was again employed for estimating the total catch and catch per unit of effort in this estuary.

Compared to that of the previous year, there has been a fall in the total fish landings from this estuarine system during the year under report. This fall is essentially due to a marked fall (about 33%) in the winter season catches from the lower zone of the Hooghly around Fraserganj. The data obtained are tabulated below:

	Zone-wise annual total catch figures	
	Weight in metric tons	Percentage
Zone I (Hooghly—upper zone) ..	399·7	11·6
Zone II (Hooghly—middle zone) ..	147·8	4·3
Zone III (Hooghly—lower zone, *plus* all other lower Sunderban areas)	2,238·9*	65·0
Zone IV (Rupnarain estuary) ..	558·4	16·2
Zone V (Matlah at Canning) ..	99·0	2·9
TOTAL ..	3,444·7	

* This figure does not include the landings at Raidighi and Hasnabad for the period July 1960 to February 1961.

Zone- and gear-wise annual catch-per-unit-of-effort figures in Kgms. and gear-wise annual total catch in M. tons

Gear	Hooghly			Rupnarain	Matlah	Entire	Total	Per-
	Zone I	Zone II	Zone III	Zone IV	Zone V	estuary	catch	centage
Bagnet ..	6·68	2·88	198·32*	6·82	15·84	6·39†	2,549·5	74·0
Purse net ..	0·58	0·83	..	..	..	0·64	51·2	1·5
Trawl net ..	2·18	1·56	.	..	..	2·15	67·3	1·9
Set barrier	9·02	..	304·92*	..	6·89	7·76	140·3	4·1
Drift net ..	1·40	1·24	..	1·15	.	1·20	90·1	2·6
Cast net ..	1·22	..	..	..	..	1·22	5·4	0·2
Lift net ..	2·94	0·46	..	..	5·18	2·51	24·6	0·7
Seine net ..	..	0·54	..	4·01	7·53	4·55	68·3	2·0
Traps ..	0·41	..	..	..	..	0·41	10·2	0·3
Hooks and lines	0·66	0·66	..	2·52	2·62	0·68	160·8	4·7
Tangle net (kochaljal)	..	..	..	..	..	..	134·7	3·9
Miscellaneous ..	..	..	..	..	..	..	142·3	4·1

* From winter fishing only. † Data of Zone III are not included.

From the above tables, it could be seen that the maximum catches were from Zone III (including all the lower Sunderban areas), contributing to 65% of the total catch, as against 75·3% the previous year. There was considerable improvement in the landings from zone II and specially IV, while there was a fall in Zone I. The last quarter was most productive taking the entire estuarine system as a whole, as well as with regard to Zones I, III and IV. But the I and II quarters yielded the maximum catch in Zones II and V respectively.

Bag net catches constituted 74% of the total catch, of which the maximum quantities were landed during the winter months November–January. Of the total bag net catches, about 66% was landed from Zone III. There was also a good bag net fishery in Zone IV.

The Clupeoids form an important component of the fisheries of this estuary, specially because of heavy catches of Hilsa, the other important

species being *Setipinna phasa*, *S. taty*, *Coilia borneensis*, *C. ramcarati* and *Ilisha elongata*.

Setipinna phasa afforded, as usual, a fishery of some importance in the upper and middle stretches of the Hooghly and the Rupnarain estuary, but it was almost non-existent at Canning on the Matlah. Taking the year as a whole, the juveniles of the '0' year group (modal length 75 mm.) dominated the catches. From March to July, the fishery was restricted to the above regions and there was a predominance of juveniles throughout this period. August–October were lean months for this species, but during the winter months November–February, the fishery spread out all over the Hooghly and Rupnarain and was clearly dominated by maturing adults (modal length 135 mm.). This marks the active breeding period of the species, when fresh recruitment to the stock takes place. Breeding continues, with less intensity, up to June and during this year it seems to have commenced earlier in Rupnarain than in the Hooghly.

Setipinna taty afforded a fishery of some standing only during November–April. It was, in the main, confined to the lower zone of the Hooghly and other lower Sunderban areas. To a lesser extent the fishery also existed in the middle zone of the Hooghly and at Canning on the Matlah, but there was practically no fishery for this species in Rupnarain this year. Maturing adults (modal length 125 mm.) dominated the catches from the Hooghly, while at Canning the catches consisted essentially of juveniles (modal length 65 mm.).

During the period March–August, the fishery, consisting mainly of immature individuals, was largely confined to Canning on the Matlah. It shifted to the lower zone of the Hooghly in the succeeding months September–November and consisted mainly of maturing adults. The fishery improved considerably in the last quarter, specially in the lower zone of the Hooghly and to some extent at Canning and it spread also into the middle zone of the Hooghly. This quarter marks the active breeding period of this species. The catch of the species during this period formed a substantial part of the total winter catches in the lower zone of the Hooghly.

Coilia borneensis is fished mainly from the Rupnarain and Matlah estuaries and to a lesser extent from the middle zone of the Hooghly. Taking the year as a whole the juveniles (modal length 48 mm.) dominated the catches, contributing to about 56% of the total catch. Maturing adults (78–108 mm.) appeared in the catches from about the end of March–September at Canning on the Matlah and from March–June in the Rupnarain

estuary. The spawning period thus appears to extend from March–September, with the months April, May and June constituting the peak period. However, a few gravid specimens, obtained from the middle and lower zones of the Hooghly during November–January, indicate the possibility of the existence of a different race of this species breeding during this part of the year. On an average, this species seems to register a growth of 7 mm. per month during the first year of its life. Its fecundity was found to vary from 598–2,558.

Coilia ramcarati affords a fishery of some importance only in the winter months in the lower zone of the Hooghly. Unlike the other species, the fishery for this species is dominated by big-sized maturing adults (78–215 mm.) and it seems to spawn during the winter months December–February in the lower zone of the Hooghly. The fecundity of this species varied from 1,939–13,850. As in the previous years, the *Ilisha elongata* fishery consisted almost wholly of juveniles (26–70 mm.) and was spread over all the zones, with the Hooghly forming the more important fishing ground. This species appears to have a perennial breeding habit.

The perches form another important constituent of the Hooghly-Matlah catches, with *Lates calcarifer* and *Sillago panijius* being the more important species. The fishing for *L. calcarifer* existed only in the lower zone of the Hooghly and other parts of the lower Sunderbans and individuals in the catches ranged in size from 75–900 mm. There were about six size-groups, with their modal lengths at 130, 190, 250, 330, 410 and 630 mm. stages. *S. panijius* was represented in the catches of all the zones throughout the year. Individuals varied in size from 35–400 mm., with the 205 mm. size-group constituting the majority. There were roughly seven size-groups, their modal lengths being 45, 75, 135, 205, 285, 335 and 385 mm. The 0 year group (modal length 45 mm.) predominated the catches during the winter months of November and December. The catches were very poor from June–August.

Mugil tade and *M. parsia* were represented in the catches from all the zones, except the upper zone of Hooghly and from the Saptamukhi and Ichamati estuaries. The individuals of *M. tade* catches ranged in size from 15–560 mm. As many as nine size-groups could be made out, their modal lengths being 45, 105, 155, 215, 275, 335, 375, 416 and 485 mm. Of these the 155 mm. group was the most predominant. The winter catches were dominated by the 215 mm. and 275 mm. groups. *M. parsia* was available in about five size-groups, their modal lengths being 45, 85, 125, 165 and

215 mm., with the first and the third groups predominating during November, December, April and May.

Horpodon nehereus constituted the major constituent of the Hooghly-Matlah-Rupnarain catches. It was available almost throughout the year in the middle and lower zones of the Hooghly and in the Rupnarain and Matlah estuaries. In the winter fishery around Fraserganj, this species formed 65% of the season's total catches, as against 47% the previous year. The size ranged from 20–380 mm. with about 6 size-groups, their modal lengths being 85, 115, 165, 215, 275 and 325 mm. respectively. The '0' year group (modal length 85 mm.) predominated the catches from March–October, while during the winter months the fourth size-group (modal length 215 mm.) was the most dominant. Large quantities of the latter size-group were landed at the lower zone of the Hooghly.

The Sciaenids, comprising in the main *Pama pama*, *Sciaenoides biauritus* and *Sciaena miles*, also contributed substantially to the total catch. *P. pama*, which was the most predominant of the three, occurred in the catches from all the zones of the estuary during different months of the year. 0, I and II (modal sizes 25, 125 and 205 mm.) year groups contributed to the catches from the upper and middle zones of the Hooghly and Rupnarain during the months March–May. During the rest of the months II and III year groups (modal size 345 mm.) formed the fishery in the lower zone of the Hooghly and lower Sunderban areas. Adults, belonging mostly to the III year group, in an advanced stage of maturity and spent condition occurred mainly in the upper and middle zones of the Hooghly and Rupnarain during January and February and June–August. '0' group individuals dominated the fishery in the summer and rainy seasons whereas the II year group was abundant during winter.

S. biauritus and *S. miles* were comparatively poor and were fished mainly from the lower Sunderbans during the winter months. They were also available in the middle zone of the Hooghly and in the Rupnarain and Matlah estuaries. Both were represented by three size-groups, with their modal lengths at 65, 85 and 115 mm. levels in the case of *S. biauritus* and at 35, 75 and 125 mm. levels in the case of *S. miles*.

Eleutheronema tetradactylum and *Polynemus paradiseus* constituted the major portion of threadfin catches. *E. tetradactylum*, ranging from 21–500 mm., was represented in the catches by four size-groups, their modal lengths being 130, 190, 290 and 410 mm. respectively. Of these, the bigger size-groups (of modal length 190 mm. and above) were caught mainly from

the lower Sunderbans during the period January–March, while the younger size-group (modal length 130 mm.) was common in the middle zone of the Hooghly and at Canning on the Matlah during August and September. At Itindaghat on Ichamati, juveniles (modal length 120 mm.) dominated the fishery throughout the year. *P. paradiseus* (26–305 mm.) was represented in the catches by four size-groups, with their modal lengths at 60, 130, 190 and 255 mm. respectively. The winter catches in the lower Sunderbans at Canning on the Matlah and at Itindaghat on the Ichamati consisted mainly of bigger size-groups (of 130 and 190 mm.), while juveniles (modal length 60 mm.) dominated the winter catches in Rupnarain and during June and July in the upper and middle zones of the Hooghly. Maturing and mature adults (modal length 140 mm.) appeared in the catches at the upper and middle zones of Hooghly from April–June and from May–July in the Rupnarain, which form the spawning grounds during this period.

The Ribbon-fish fishery, consisting essentially of *Trichiurus savala* and *T. haumela*, showed considerable decline during the year. The catches were almost confined to the lower Sunderban areas during the winter months. The Ribbon-fish catches during this year's winter fishery around Frasergunj constituted only 5% of the total catch. *T. savala* was represented in the catches by four size-groups (modal vent lengths at 57, 83, 113 and 163 mm. respectively) in the lower zone of the Hooghly and by one size-group of juveniles (modal vent length 57 mm.) in the middle zone of the Hooghly and in Matlah. *T. haumela*, represented by two size-groups (modal lengths 70 and 120 mm.), was almost confined to the lower zone of the Hooghly, with a few stray individuals in the Matlah and Rupnarain.

Catfishes formed an important group, *Pangasius pangasius*, *Tachysurus jella* and *Osteogeneiosus militaris* being the more important species. Four size-groups of *P. pangasius* representing 0 to III year groups contributed mainly to the fishery in various zones of the estuary. 0 and I year group fishes formed the bulk of the landings in the upper and middle zones of the Hooghly and Rupnarain, whereas the bigger size-groups were abundant in the catches of the lower zone and lower Sunderbans. *T. jella* was represented in the catches from the lower Sunderbans during the months August–January by individuals ranging in size from 600–900 mm. Smaller size-groups representing I and II year classes (modal lengths 115 and 205 mm.) contributed to the catches from Rupnarain and middle zone of the Hooghly. *O. militaris* was represented in the catches from the lower and middle zones of the Hooghly and Rupnarain during the period March–July by I to III year groups. 0 year class individuals, along with II and III year classes,

contributed to the fishery in the lower Sunderbans during winter months. Observations during the current year confirmed the conclusion that the fish spawns in the middle zone of the Hooghly and Rupnarain during summer months.

The prawns formed a substantial part of the total catch from this estuarine system. However, its proportion in the winter fishery catches around Frasergunj fell considerably during the year. Of the five selected species, *Palaemon mirabilis*, *Laender styliferus* and *Metapenaeus brevicornis* were landed in larger quantities. As in the previous year, *P. mirabilis* continued to dominate the catches in the upper and middle zones of the Hooghly all through the year. Small juveniles (11–20 mm.) were represented in the catches from August–March, and juveniles of 13 mm. and over occurred in all the zones. Berried and maturing females occurred all the year round. Females in early stages of maturity were obtained from the upper and middle zones, while those in the final stages of maturity occurred only in the lower zone of the Hooghly. This species was represented by three size-groups, their modal lengths being 25 mm. (June and August–December), 35 mm. (April–July) and 45 mm. (all through the year). *L. styliferus* was represented mainly from the catches of Matlah and lower zone of the Hooghly by five size-groups, their modal lengths being 29 mm. (March–April and October–November), 42 mm. (January–October), 60 mm. (February and April–December), 75 mm. (October–May) and 87 mm. (December–April). This species seems to have a prolonged breeding season from September–June, the peak period being the winter months. Juveniles below 45 mm. were commonly fished from the Matlah and to a lesser extent from the lower zone of the Hooghly, while all the adults above 70 mm. were caught only from the lower Sunderban areas.

M. brevicornis constituted the most abundant species of prawns in the lower zone of the Hooghly and in the Matlah and was present also in the Rupnarain estuary. It was represented by five size-groups, their modal lengths being 38, 47, 59, 89 and 101 mm. respectively. Large-sized males and females occurred in the lower zone of the Hooghly, while juveniles below 60 mm. were quite common at Canning, the upper reaches of the lower zone and the middle zone of the Hooghly and in Rupnarain. Specimens with maturing or mature gonads were not seen in the samples.

P. carcinus was represented by juveniles (47–116 mm.) mainly in the upper zone of the Hooghly during the months of July–November and by maturing and mature female adults (128–210) mainly in the middle zone from

December–June. Large-sized males (106–202 mm.) also occurred in the middle zone, but they were all found to be immature. It is noteworthy that mature adult males and juveniles below 46 mm. were not met with in the catches. *P. malcolmsonii* ranging from 25–120 mm. was caught mainly from the upper zone of the Hooghly and to a lesser extent from the middle zone. Only juveniles and adult females were represented in the catches. The spawning period of the species was spread over the period June–August.

23. *Investigations on the Fisheries of the Mahanadi Estuarine System*

A market survey of dry and fresh fish for estimating the total fish production from the estuary and a separate water zonation sampling programme for estimating the catch-per-unit-of-effort, as well as the total catch, were initiated during the year.

There was marked improvement in the Hilsa fishery of the Mahanadi estuary after a lapse of several years. Heavy catches were landed from about the middle of December 1960 to the end of February 1961, with the daily catch going up to about 400 mds.

With the improvement in weather conditions in the third quarter, there was considerable improvement in the intensity of fishing in the estuarine system and fairly good quantities of fish were landed. The catches continued to improve in the last quarter also, which usually marks the period of maximum fishing intensity.

Gill nets, seines, bag nets and drag nets were the commonly employed gear. The gill net catches consisted mainly of *Polydactylus indicus*, *E. tetradactylum*, *Lates calcarifer*, *Pama pama* and big-sized prawns in the Paradip-Lower Mahanadi area (Zones VI and VII), of the above and catfishes like *Pangasius pangasius*, *Plotosus canius*, etc., and *Setipinna phasa* and *Thrissocles* spp. in the Jamboo-Hukitola area (Zones I, II and III), of sciaenids and catfishes in the Narayanpur-Ostar region (Zones IV and V) and of *Lates calcarifer*, *Polydactylus indicus* and *Arius* spp. at Jatadharmohun (Zone VIII). The catches by seines consisted essentially of mullets, Bhetki, polynemids, catfishes, sciaenids, engraulids and prawns in the Jamboo-Hukitola and Paradip-Lower Mahanadi areas and occasionally freshwater carps like Rohu and Catla in Paradip region at low salinity period. In the Narayanpur-Ostar area the seines landed mainly catfishes, sciaenids, and Bhetki and occasionally some carps like Mrigal. In Jatadharmohun the seines landed mainly large-sized mullets, catfishes and sciaenids. Drag nets were operated mainly in Jatadharmohun, with the catches consisting of prawns and small-sized miscel-

laneous fishes, mainly mullets. The same net operated in the Paradip-Lower Mahanadi area landed bigger fish like Bhetki and sciaenids. The bag nets were operated extensively in Jatadharmohun and Hukitola regions and the catches consisted essentially of prawns.

The figures of total landings estimated from the market survey of fresh and dry fish are tabulated below. These exclude figures relating to subsistence fishing and the fish disposed off outside the markets, either by hawking or by local disposal near the fishing ground (The weight of dry fish has been multiplied by 2·5 to get their fresh weight).

Estimates of total landings in kg. for the year 1960–61

	Weight of fish marketed in dried or cured condition	Weight of fish exported in fresh condition	Total catch	Percentage
Mullets ..	1,61,055	10,237	1,71,292	22·01
Prawns ..	62,208	7,605	69,813	8·97
Polynemids ..	34,162	2,867	37,029	4·76
Sciaenids ..	34,338	2,818	37,156	4·77
Bhetki ..	17,150	12,741	29,891	3·84
Clupeoids (excluding Hilsa)	64,035	4,030	68,065	8·74
Hilsa ..	52,475	2,49,892	3,02,367	38·84
Catfishes ..	14,542	1,890	16,432	2·11
Miscellaneous .	29,768	16,601	46,369	5·96
TOTAL ..	4,69,733	3,08,681	7,78,414	

The mullets contributed to as much as 22·01% of the total Mahanadi estuarine catch and were second only to Hilsa. The species contributing to this fishing were *Mugil cephalus*, *M. troscheli*, *M. parsia* and *M. cunnesius*. *M. cephalus* ranging in size from 15·0–64·8 cm. was caught mainly from the lower stretches of the estuary almost throughout the year. They were available in all the zones, except the Zones IV and V and the majority were in the

size range of 25·0–40·0 cm. The size-group measuring 30·0–34·9 cm. constituted the modal group in June, September, October, January and February, while in April and May bigger size-groups (modal length 37·5 cm. and 42·5 cm. respectively) predominated the catches. *M. troscheli*, ranging in size from 15·0–64·9 cm. were also obtained from the lower stretches of the Hooghly, but they formed a comparatively poor fishery.

M. parsia, ranging from 7·0–24·0 cm., occurred in fairly large numbers in the lower stretches of the estuary, with the great majority of them within the size range of 13·0–18·9 cm. Taking the year as a whole, the 18·5 cm. group constituted the mode, closely followed by the 17·5 cm. group. During the monsoon months this species hardly afforded any fishery, while big-sized individuals (modal length 18·5 cm.) were encountered in large numbers in the month of November. *M. cunnesius* also occurred essentially in the lower stretches of the estuary and ranged in size from 5·0–21·0 cm. It was represented in the catches mainly by two size-groups, their modal lengths being 10·0 and 15·0 cm. respectively.

Lates calcarifer contributed to 3·84% of the total catch and among the fresh fish exported out, it was second only to Hilsa. It was represented in the catches by roughly about six size-groups, their modal lengths being 27·0, 39·0, 45·0, 55·0, 61·0 and 81·0 cm. respectively. The majority were within the size range of 18·0–45·0 cm.

The Polynemids also formed a significant portion of the total catch (4·76%). They were represented in the catches mainly by *Polydactylus indicus* and *Eleutheronema tetradactylum*, both of which occurred only in the lower stretches. *P. indicus*, varying from 15·0–85·0 cm., was available in the catches from September–April, while *E. tetradactylum* varying from 10·0–52·0 cm. occurred from December–May.

The Clupeoids excluding Hilsa contributed 8·74% of the total catch. They consisted mainly of *Thrissocles* spp., *Ilisha* spp., *Setipinna phasa* and *Anchoviella* sp.

24. *Hydrobiological Observations*

The surface water temperature in the Hooghly ranged from 21·09–32·08° C., while in Rupnarain and Matlah from 20·83–31·42° C. and 20·72–31·20° C. respectively. In the Matlah and Rupnarain, the salinity ranged from 11·80–28·86‰ and traces to 4·40‰ respectively. In the Hooghly three salinity zones could be distinguished, an upper zone from Medgachi to Khusigoli with a range of traces to 0·6‰, a middle zone from Khusi-

goli to Nurpur with a range of traces to 9·92‰ and a lower zone from Nurpur to Frasergunj with a range of 1·14–30·10‰.

The phytoplankton production continued to be poor during the earlier part of this year. However, there was a gradual improvement in the post-monsoon months, specially in the upper and lower zones of the Hooghly. Freshwater and marine forms predominated in the upper and lower zones respectively, while both freshwater and brackish-water species were present in the middle zone and in Rupnarain. At Canning on the Matlah, the marine element was again predominant. *Coscinodiscus*, *Melosira*, *Synedra* and *Surrirella* among the diatoms and *Spirogyra*, *Pediastrum* and *Eudorina* among the algae dominated in the upper zone, while in the lower zone the most common forms were *Biddulphia*, *Chaetoceros*, *Lithodesmium*, *Coscinodiscus*, *Triceratiun*, *Thallassiothrix* and *Trichodesmium*. The main phytoplankters along the middle zone of the Hooghly and the Rupnarain estuary were *Coscinoidiscus*, *Melosira*, *Syndedra*, *Nitzschia*, *Pediastrum*, *Eudorina* and *Spirogyra*.

The Zooplankton population also showed gradual decline in the Hooghly and Matlah till the onset of rains. Rotifers (*Brachionus* spp. and *Keratella* spp.) accounted for the increase in Zooplankton population in the Rupnarain during this period. Quantitatively, the freshwater copepods (*Diaptomus* spp. and *Cyclops* spp.) dominated the plankton in the upper and middle zones of the Hooghly and at Rupnarain, while in the lower zone of the Hooghly and in Matlah, the euryhaline copepods were found to be predominant.

25. *Larval and Young Fish Survey*

The study of the distribution and fluctuations in abundance of fish eggs, larvae and young fish of the Hooghly-Matlah and Mahanadi estuaries was continued. In the Hooghly-Matlah system, larvae and post-larvae of *Hilsa ilisha*, *S. phasa*, *P. paradiseus*, *E. tetradactylum*. *P. pama*, *Coilia* spp. and *Mugil* spp. were obtained in the various zones. Those of *H. ilisha* (July–November) and *S. phasa* (February–December) were restricted to the upper and middle zones of the Hooghly and the Rupnarain, while those of *P. pama* and *Mugil* spp. were obtained in all the zones throughout the year. Larvae and post-larvae of *P. paradiseus* were seen in the collections of Zones I, II, III and IV from April–November, while those of *E. tetradactylum* from March–August in Zones III, IV, V and the lower reaches of Zone II. Larvae of *Coilia* spp. were available from April–June in Zones II, III, IV and V.

In the Mahanadi estuary, the areas rich in fish eggs, larvae and juveniles were North and S.W. Hukitola, Paradip, lower Mahanadi and Jatadharmohun (Zones I, II, VII and VIII respectively). Clupeoids were the dominant group (71·7%), the rest consisting of perciformes and other orders (20·6%), carps (1·5%) and fish eggs (6·2%). *Anchoviella* sp. accounted for 57·1% of the clupeoids and with the sole exception of Zone III, post larvae and juveniles of this species, ranging from 6·0–37·0 mm., were available in all the zones during June–February. Juveniles of *Thrissocles kammalensis*, ranging from 17·0–61·0 mm., formed 11·6% of the clupeoids and their availability was almost restricted to Zone III in the month of November. Post-larvae of *Megalops* sp. ranging from 11·0–33·0 mm. occurred from June–August in Zones II, VI and VIII. Other clupeoids met with were *Coilia* sp. and *Corica soborna*. Top-minnows and carps included *Chela* sp., *Haplochilus melanostigma*, *Perilampus* sp. and *Labeo* sp. Post-larvae and juveniles of *Sicydium* sp. (Gobeidae), ranging from 8·5–20 mm., were available in almost all the zones practically throughout the year. Other larvae and juveniles encountered mainly in the lower stretches were of *Ambassis* sp. (7·0–17·0 mm.), *Pama pama*, *Sciaenoides* sp. (6·0–8·5 mm.), *Leiognathus* sp. and *Mugil* sp.

26. *Studies on the Culture of Brackish-Water Fishes*

The Brackish-water fish culture unit continued its work at the Kiragachamadeli fish farm in Orissa and carried out experiments to study the effects of different types of manures, salinity, pH, depth, turbidity and temperature on the growth of benthic algae. The two different types of manures tried consisted of green manure (decomposed leaves of *Sonneratia apetale*) and chemical fertilizer NPK. Three tanks were manured with green manure at 2,500 lb./acre, four others with NPK in the ratio of 10: 10: 6 at the rate of 200 lb./acre and 3 tanks were kept as controls without any manuring. Mullet fry were stocked in all the tanks at the rate of 1,500 per acre. It was found that the benthic algae grew only during the period December–July. The mullet fry were found to grow faster in the tanks manured with NPK than in those treated with green manure.

In order to determine the optimum salinity to be maintained in Brackish-water fish farms, pot culture experiments were carried out at Barrackpore. It was found that in most cases the concentration of ammoniacal and nitrate nitrogen in the water was highest within the salinity range 10-20‰, while the exchangeable ammoniacal nitrogen in the soil, after an initial gradual decrease up to a salinity of 20‰, increased with higher salinities. It may, therefore, be said that the farm water, having a salinity between 10 and 20‰,

offers a better medium for the growth of floating organisms which derive their nutrients from the water, while salinities higher than 20‰ are favourable for the growth of benthic algae which depend for their nutrient requirement on the exchangeable complex.

Another set of experiments were carried out to study the influence of salinities on the transformation of nitrogen added to the soil in the form of fertilizers like ammonium sulphate, urea or sodium nitrate and to see whether NaCl can check the loss of nitrogen in the form of gas from the above fertilizers when applied to fish farms. It was found that the loss of nitrogen in 10 and 20‰ salinities was less by 30 and 40% respectively than in the 0‰ salinity and that higher salinities maintain a much greater amount of nitrogen in available form, both in soil and water than the 0‰ salinity.

27. *Investigations on Hilsa Fisheries of India*

The second and the fourth quarters of the year formed the main fishing seasons for Hilsa. There was a fairly good monsoon fishery in the Hooghly, Mahanadi, Godavari, Krishna, Cauvery, Narmada, Tapti and the Ganga rivers, in the Chilka Lake, and on the Sourashtra coast.

The monsoon fishing for Hilsa in the Hooghly was confined to the lower zones in July and September and was more intensive in the upper zone in August. The winter fishery for Hilsa in the Hooghly commenced rather late, by February, and was of a short duration, the fishery coming to a close by the middle of March. Large numbers of Hilsa were caught during this period in the upper zone (near Barrackpore). The total estimated catches of Hilsa in the Hooghly-Matlah system during the period March 1960 to February 1961 was 634·16 metric tons.

In the Godavari, the monsoon fishery was of an appreciable magnitude, but started, later than usual, late in August. The maximum catches were recorded during October, when 547 metric tons of Hilsa were landed. The winter fishery in the Godavari was comparatively poor. Mostly Rangoon nets were operated during the monsoon in all the six centres sampled. In the winter season, however, nets like Ailavala, Taruchuvala and Kattuvala were also operated in some centres. The catch-per-unit-effort relating to the Rangoon net, which is the main Hilsa catching net in the Godavari, in the different sampling centres, was as below:—

	kg.
Dowlaiswaram	.. 5·63
Kotipalli	.. 1·18
Bodasukkuru	.. 0·79
Rajole	.. 0·76
Injaram	.. 1·53

The Hilsa fishery in the Krishna was only of a small magnitude, commencing in August and continuing up to the end of October. Mostly Rangoon nets were operated. Estimated total catch during the season was 1·81 metric tons.

In the Padma, the maximum landings were recorded during the monsoon and post-monsoon months. The heaviest landings were in July and October, when 128·7 and 147·1 metric tons respectively were landed. The winter catches were comparatively less, the maximum being about 64·0 metric tons in March. The total landings of Hilsa in the Padma during the year has been at about the same level as in the preceding two years. Mainly Chandi jal (drift gill net), Kharke jal and Sangla jal (purse net) and Bauli jal (lift net) were operated during July–March and Konajal during July–November. Occasionally Patan jal, Ghana kona, Tana ber and Ghano ber jal were also operated. The catch-per-unit-effort pertaining to the more important Hilsa nets operated in Lalgola during the year are given below:

	kg.
Chandi jal	.. 4·15
Sangla jal	.. 0·78
Kharke jal	.. 0·43
Bauli jal	.. 0·56
Kona jal	.. 6·78
Patan jal	.. 4·59

The total landings of Hilsa in the Ganga from Kanpur to Rajmahal during the year was 200·098 metric tons and in Mahanadi 302·37 metric tons.

The Hilsa catches in the Hooghly comprised of 0–5 year age groups. In the monsoon fishery the '0' and '1' year groups predominated in the

catches in July and thereafter the ' 3 ' to ' 5 ' year groups. In the winter the '1' to '2' year groups were the mainstay of the fisheries.

Hilsa, classifiable under the age groups 1–5 years, formed the fishery in the Padma and the Ganga, but the majority groups in the catches were ' 2 ' to ' 3 ' year old fish. In the Godavari ' 2 ' to ' 5 ' year groups contributed to the fishery in the monsoon season (the ' 3 ' year olds predominating), while in winter the fishery was mainly for the ' 1 ' year group. In the Chilka lake and in the Mahanadi the Hilsa catches comprised mainly of fish classifiable as ' 1 ' to ' $4\frac{1}{2}$ ' year age groups, with the 2nd year group predominating. The Hilsa caught in the Sourashtra coast were mostly of the larger size-groups, measuring between 35·0 cm. and 66·0 cm. in total length.

Studies on the maturity of Gonads of Hilsa caught from Padma (in the neighbourhood of Lalgola) indicated that maturing or spent recovering fish were present in the area throughout the year. Mature Hilsa were present in the catches during the breeding seasons, the monsoon and the winter. The largest percentage of mature fish were obtained in October and March. Tow net collections made at Lalgola yielded a few Hilsa larvae in November. Since the main fishing grounds in the river (in the neighbourhood of Lalgola) lie within Pakistan, it has not been possible to demarcate the spawning area.

Samples of Hilsa obtained from the Mahanadi during January consisted mostly of spent recovering females. Of these, about half the number had empty guts. The rest were found to have fed mainly on phytoplanktonic organisms like diatoms and the green algae *Spirogyra*. Study of a large number of samples of juvenile Hilsa collected in the Hooghly showed that these feed mainly on plankton. No selectivity of planktonic organisms could be noticed. Study of the gut contents of juveniles from Godavari revealed that they had also fed largely on plankton. Among the phytoplankton, diatoms formed the chief constituents of the food. Zooplanktonic constituents included rotifers, copepods, ostracods, arachnids and larvae of crustacea, bivalves and gastropods.

The Hilsa caught in the Godavari during the monsoons were all adults. Fully mature and oozing fish were obtained during September, October and November. A few spent fish were also present in the samples during October and November. Tow net collections made below the anicut at Dowlaiswaram yielded Hilsa larvae and post-larvae during November. The fecundity of Hilsa caught in the Godavari during the monsoon seasons of 1959 and 1960 have been found to vary between 5,00,000 and 11,40,000.

During the year under report, 4,507 Hilsa were tagged and released in the Hooghly, the Padma and the Ganga for the purpose of studying the migration of Hilsa in these rivers and also to determine whether the Hilsa in each of the rivers form discrete populations or they intermingle to any appreciable extent. With adequate publicity among fishermen and fish traders, it was possible to obtain 12·2% recoveries in the Hooghly. Due to the practical difficulties in obtaining recovered tags from East Pakistan and in paying reward to the fishermen there, the recovery from River Padma was only 4·3%. The recovery from the Ganga was 2·9%. Nearly 80% of the tagged fish were recovered within a month after tagging. The longest time interval between tagging and recovery was 770 days. The results obtained so far indicate that the fish comes up the river Hooghly for spawning more than once in its lifetime. The Hilsa of the winter run have been observed to come up the river for spawning in the following or subsequent monsoon seasons and *vice versa*. This supports the view that the Hilsa of the monsoon and winter runs do not form separate stocks. The movement of Hilsa migrating for spawning does not appear to be always upstream. However, there is evidence of greater downstream migrations during the later halves of the monsoon and winter seasons. The speed of migration appears very variable. There seems to be no movement of Hilsa from the Hooghly to the Padma or the Ganga, and very little intermingling of the populations of Hooghly, Padma and Ganga.

28. *Sunderbans Fisheries*

Exploratory surveys of the estuarine systems of the Sunderbans, bottom contour surveys and fishing operations were continued using the exploratory fishing vessel, M.V. " Sunderbans ".

For the first time, the exploratory fishing operations and charting of bottom contours were conducted in the Sunderbans waters during the monsoon season also. These activities were mainly confined to the estuary of Saptamukhi and other smaller rivers and canals like Gobadia Gang, Mural Gang, Baghchira nadi and Martin's creek. Operations in other areas were not possible due to unfavourable conditions caused by monsoon. The Saptamukhi estuary was explored quite extensively and found suitable for all-weather operations.

During the winter season, the estuary known as Jagdal Gang lying in between Saptamukhi and Thakuran estuaries was explored. It was found quite suitable for trawling operations between 6 and 10 fathom line towards

the lower reaches and the catches were also satisfactory. Lower reaches of Thakuran estuary near the sea face were also explored for the first time and a ground within 6 fathoms depth appeared suitable for trawling operations.

Otter trawl net was mostly used for conducting fishing operations. Drift gill net (1·5″ and 3″ mesh) were employed on few occasions but no fish could be caught in them. From a preliminary study of the data collected during the year, it was seen that Zone II (Thakuran and Matlah) yielded the highest value for catch per unit of effort and the Zone I (Muriganga and Saptamukhi) the lowest. Altogether 213 hauls were made, catching 407 kg. of fish from 3 zones. *Harpodon nehreus* formed the main constituent and contributed 46·56% of the total landings. The catch was highest in Zone II during the winter months. The catches comprised mainly of ' 3 ' size-groups having modal lengths 8·5, 15·5 and 23·5 cm. Sharks and Rays came second in order (14·89%), *Trygon bleekari*, *T. wagla*, *T. sephen*, *Pteroplatea micrura*, *Carcharhinus laticaudus*, *Pristis cuspidatus* and *Rhynchobatus djiddensis* being the species caught. Percentages of catch in the 3 zones were 16·23, 4·26 and 8·3 respectively. Sciaenids constituted 12·94% of the total landings. The group was mainly represented by *Pama pama*. *Sciaenoides biauritus*, *Sciaenoides brunneus*, *Sciaena glaucus*, *Sciaena miles* and *Otolithus maculatus* were found rarely. Sciaenids formed 18·5% of the catch in Zone I, 4% in Zone II and 11·7% in Zone III. Prawns formed the fourth big group and accounted for 9·78% of the catch, *Parapenaeopsis sculptiles* and *Leander tenuipes* being the dominant species. Catfishes (6·88%) were represented by *Arius sona*, *Arius nenga*, *Pangasius pangasius* and *Osteogeneiosus militaris*. Individuals of *A. nenga* and *O. militaris* with fertilised eggs in their mouth cavities were obtained in the Saptamukhi estuary during August and September. *Arius sona* contributed the bulk of total catch of catfishes, their size ranging between 60 and 76 cm. Clupeids (3·29%) were represented by *Coilia ramcarati*, *Setipinna phasa*, *Setipinna taty* and *Ilisha motius*. *Muraenesox telabonoides* (2·90%) was the only eel caught and was mostly from the lower Saptamukhi, west of Lothian Island. This size varied between 58·2 cm. and 139·7 cm.

Chilka Lake Investigations

29. *Fisheries of the Lake*

2603·6 tonnes of fish were brought to the Chilka Assembly Centres during the year 1960. Nets with 54 different names have been encountered in the lake. Depending on the mode of operation and manner of fish

capture, they have been classified into 14 types. Unstandardised state of Chilka nets is a great handicap in catch-per-unit-of-effort studies. Hence, during the year under report 5 Nos. of identical departmental gill nets made of ' Terylene ' were regularly used during nights at selected centres in different sectors of the lake. Each of these nets, 152 metres × 1·8 metres, are composed of 5 pieces (30·4 m. × 1·8 m.), of mesh sizes 25 mm., 38 mm., 51 mm., 64 mm. and 76 mm. The values for monthly catch per unit of effort (catch per net per night) are tabulated below:

Months	Catch per net per night (gm.)					
	Eleutheronema tetradactylum	*Nematalosa nasus*	*Pseudo-sciaena coibor*	*Mystus gulio*	*Arius*	All species pooled
April 1960 ..	226	14	106	48	91	761
May ..	395	48	85	77	41	1,053
June ..	194	47	122	216	49	1,149
July ..	333	31	76	18	40	1,113
August ..	235	19	37	14	..	1,046
September ..	824	14	69	7	66	1,703
October ..	327	8	143	7	70	1,338
November ..	291	17	227	18	48	1,442
December ..	244	..	68	..	34	814
January 1961	295	36	284	4	13	1,317
February ..	285	23	303	11	21	1,542
March ..	171	12	299	9	64	1,728

The catch per prawn trap (in gm.) for the year 1960 was estimated to be ' Daudi '—144 and ' Bazza '—44.

Routine observations on the species and size composition of landings at the different sectors were continued. The percentage composition of all important species have been recorded for each month.

30. *Biological Observations on Commercial Fisheries*

The production of *Mugil cephalus* was 180·7 tonnes in 1960. The average length of the fish was 323·8 mm. By numbers, zero and 1st year

class (up to 350 mm.) have constituted 81·5, 63·4, 65·0 and 70·7% of the production during the years 1957–60 respectively; II year class (up to 500 mm.) between 15·9% and 31·5% and year class III and above have contributed between 1·5% and 6·0%. Tagging operations have confirmed the observation that males of *M. cephalus* ripen and migrate to sea at age 'I' and females at age 'II' and above. Most of the recoveries of tagged fish within the lake during the period January–April comprised of immature females estimated to be I year olds. The fish breeds in the sea during the period October–December and attains an average length of 340 mm., 510 mm., and 625 mm. at the end of 1st, 2nd and 3rd years of its life respectively. Nearly 43–54% of the catches by weight comprise fish of the 0 and I year class, 35–46%, II year class and 10·5–20% of the III year class. Large-scale inward migration of the species was observed during May–August 1960.

33·8 tonnes of *Liza troscheli* were landed during the year and the mean length was 283·9 mm. The number and weight obtained during the year of the different year classes of specimens are given below:

Year class	Percentage values of	
	No.	Weight
Zero and I	48·25	20·16
II	43·00	51·06
III	8·03	25·19
>III	0·72	3·59

One female specimen, which measured 235 mm. at the time of tagging on 28–11–1959, was recovered on 23–12–1960 and measured 398 mm. (ripe, stage IV). *Liza troscheli* has been found to breed in the sea during the period January–April.

Among prawns, 575·1 tonnes of *Penaeus indicus* and 298·3 tonnes of *P. semisulcatus* were estimated to have been landed during the year. The average lengths were 113·42 mm. and 153·0 mm. respectively. The post-larvae of the prawns were observed to enter the lake with the tide throughout the year except during monsoon months when there is a general unidirectional sea-ward flow of freshwater throughout the lake.

193·0 tonnes of *Eleutheronema tetradactylum* were landed during 1960. The fish has been found to breed in the lake over a prolonged period, January–June, with peaks in February and May. The earlier broods attain average lengths of 300 mm. and 460 mm. and the later, 275 mm. and 450 mm. when one and two years old respectively. The average length of the fish available in commercial gear was 250 mm. and mortality rate worked out to 0·71. The juveniles of the size range 51·77 mm. were found to occur in large numbers in Patua jal catches during July and formed a mode at 88 mm. class in August. The December 1959 brood, which formed a mode at 113 mm. class in May 1960, could be traced up to 188 mm. class in August. Stomach contents of the fish up to 100 mm. total length showed 65·7% Mysids, 24·6% Amphipods and 6·8% Copepods. Larger fish subsist on prawns, fish (mostly *Mystus gulio*) and Stomatopods (*Squilla* sp.).

Pseudosciaena coibor was the most commercially important sciaenid fish. 128·3 tonnes of the fish were landed during 1960. This species breeds in the lake off Daya river mouth during April–July, May being the peak month of spawning. It attains a length of 260 mm., 410 mm. and 510 mm. at the end of the first three years of its life. 23·1% of adult females examined showed immature ovaries, 74·4% maturing and mature ovaries and 2·6% spent ovaries. Fecundity increased from 23,750 in 247 mm. specimen to 23,27,500 in 728 mm. ones. The food of the fish of size-group 76·0–275·0 mm. was debris and fish (30% each) and amphipods and prawns (about 17·6% each). Large fish feed on prawns (40%), stomatopods (38%), debris (20%) and fish (2%).

102·2 tonnes, 37·0 tonnes and 26·4 tonnes of *Lates calcarifer*, *Gerres setifer* and *Sparus sarba* respectively were landed during 1960. *G. setifer* breeds in the lake from May–August in the Southern and Central Sectors of the lake. The minimum sizes at maturity of male and female specimens are 73 and 86 mm. respectively. The fish attains a length of 110 mm. and 175 mm. at the end of the first two years of its life.

Sparus sarba breeds in the sea from November–January, the peak month of spawning being December. The minimum size at maturity of female and male specimens are 172 mm. and 153 mm. respectively. The fish attains a length of 175 mm., 250 mm. and 325 mm. at the end of the first three years respectively of its life.

124·1 tonnes of *Nematalosa nasus* were landed during the year. This fish breeds in the lake during June–July. During January–December, a regular influx of the species occurs from the sea adding to the Chilka stocks

of fish. No seaward migration has been noticed. The fish attains 135 mm., 215 mm. and 260 mm. in the first three years of its life. The mean length available during the year to commercial gear was 150·4 mm. The annual mortality rate was 0·92.

Hilsa ilisha is known to ascend river Daya and breed there and also in the Northern sector of the lake. 100·6 tonnes of the fish were caught during the year and the mean length was 262·1 mm. The average lengths attained by Hilsa in the first four years of its life have been calculated to be 150, 265, 350 and 420 mm. respectively. The annual mortality rate worked out to 0·91.

31. *Physico-Chemical Features of the Lake*

Average monthly temperature varied between 22·9° C. and 30·3° C., the maximum being in September and minimum in January. The pH ranged between 8·1 and 8·9, the maximum being in December and minimum in July. Transparency fluctuated between 45·1 cm. and 89·8 cm. Dissolved oxygen varied between 5·0 and 7·5 p.p.m. Total alkalinity was between 68·2 and 109·6 p.p.m., phosphates recorded a variation from 0·008–0·04 p.p.m., nitrate nitrogen 0·015–0·12 p.p.m., iron 0·001–0·025 p.p.m. and silica 1·8–4·1 p.p.m. Maximum salinity values ranged from 32·45‰ in the lake mouth area to 19·57‰ at Kaluparaghat. The minimum values varied between 19·57‰ in the lake mouth and 0·48‰ at Kaluparaghat.

Fish Pathology Investigations

32. *Studies on Fish Mortality in Jute-retting Tanks*

The biological data obtained during the year under both laboratory and field conditions have been analysed and the results generally confirmed the earlier observations. The increase in zooplankton production on applying the initial charges of jute was pronounced and the bloom was found to decrease with addition of jute. A detailed report on the investigations made has been prepared.

33. *Fish Diseases and Mortality*

Observations on the new type of eye disease which has caused large-scale mortality of *Catla catla* were continued. Reports on the occurrence of the disease in some villages of Orissa State were also received. Cultures prepared from the eyes in primary stages of infection did not show the presence of any bacteria. This appears to suggest that the disease might probably be virus in origin. It is also likely that vitamin deficiencies are associated. Good growth could be obtained in media prepared with fish extract following

the " trout-tissue " extract developed by Sniezko and Bridle. A few experiments were conducted by sub-cutaneous inoculation of Catla fingerlings in glass jars, but no infection could be induced.

Incidence of ' Dropsy ' disease in an epidemic form in a big tank was controlled satisfactorily. Artificial inducement of ' Dropsy ' under laboratory conditions has been undertaken. Some of the attempts made were successful. The infection was induced using fluid collected from body cavities of infected Catla.

Parasites of Hilsa obtained from Chilka Lake, Lalgola, Allahabad, Bombay, Verawal, Barrackpore and Cuttack were studied in detail. The parasites so far described include Fellodistomes, Tetrarhynchids, Hemiurids and Cestode larvae.

Preliminary observations on the heavy parasitic infection of fish in the Barwar reservoir (Uttar Pradesh) were completed. A number of collections were made from the reservoir as well as from the Mauranipur market. The most important infection observed was caused by the trematode *Isoparochis hypselobagri*. These trematodes were found in large numbers in almost all the catfishes collected from the reservoir and were generally present in the swim bladders and body cavities of the hosts. Since the Barwar reservoir covers a large area, the cost of chemical treatment would be very formidable. But it was suggested that partial control at least would result, if it is possible to reduce the catfish population. By breaking the life-history of the parasite also it will be possible to control the infection. In addition to the *Isoparorchis* infection, a peculiar type of bacterial disease was observed in many of the major carps collected from the reservoir. The symptoms observed do not exactly resemble those of any of the bacterial diseases of fish so far described, but in some respects they agree with those of the disease known as " *Lepidorthosis contagiosa*". Definite cure for this disease is not yet known.

Continuing the studies on the damage caused to fishing implements by wood borers in Chilka Lake, detailed surveys and collections were made at Sabulia, Ramba, Madurchuan and Rumba Bay in the southern sector, Balugaon, Santrapur, Gandepur, Chhedapeda, Chandraput and Barkul in the northern sector. Borer attack was significant in the southern sector only and majority of the organisms collected belonged to the genus *Sphaeroma*.

CENTRAL INLAND FISHERIES
RESEARCH INSTITUTE,
Barrackpore.

B. S. BHIMACHAR,
Director.

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The drawing on the Cover Page depicts a chank fishing scene off the South-East coast of India. The Indian sacred chank, Xancus pyrum *(Linnaeus) which supports the fishery in this region and elsewhere along the Indian coast is shown in the inset below.*

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